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JULY, 1938

WITH AN ASTRONOMER ON AN ECLIPSE EXPEDITION[1]

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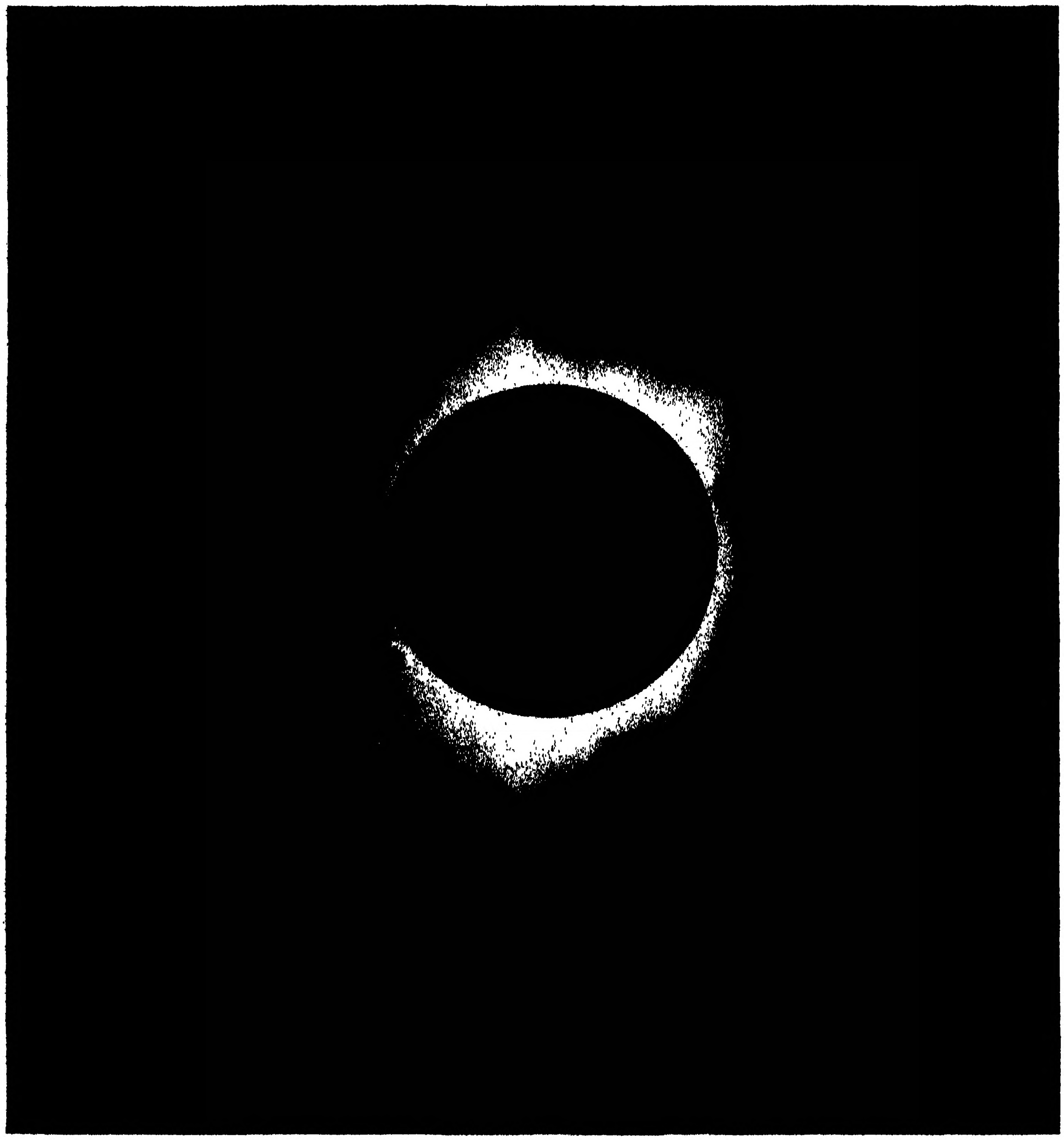
FROM the time of the earliest recorded eclipse, that of the year 2137 B.C. described in the ancient Chinese classic "Shu Ching," the coming of a total eclipse has always been regarded with fascinating interest. To-day amongst all the wonders of all the wonderful sciences there is no science which deals with such a gorgeous spectacle as that vouchsafed by nature to the oldest and most abstract of the sciences, astronomy, at the moment when the earth is gradually shrouded in darkness and when around the smiling orb of day there appears the matchless crown of glory, the corona. Nor can any science duplicate the wonderful precision shown by the work of the astronomer in his ability to predict, hundreds of years in advance, the exact hour and minute at which an eclipse will take place and the locality on the earth's surface where such an eclipse will be visible.

The modern scientific method of investigation, that of experimentation, came into vogue about the time of the 1842 total eclipse which was greeted at Milan with shouts of "long live the astronomers," who had provided so beautiful a phenomenon to please and interest the populace. The unexpected beauty of color and form of the prominences and corona, coupled with the discovery of Baily beads, and in the year following the discovery of the periodicity of sunspots, caused an unprecedented increase in interest in the physical constitution of the sun. If one of our present-day enthusiastic eclipse astronomers had been alive at that time and with long life and unimpaired vigor had been permitted to take part in each eclipse expedition from that day to this, and if he had had to take his average run of luck with the weather, he would have been permitted one precious hour of sixty golden minutes to secure all his observational material. Among all the wonders of modern science, it is safe to state that the eclipse astronomer eclipses the performances of any other scientist in the wealth of information gleaned per hour spent in securing the observations.

Photography was employed with success at the eclipse of 1860 and by its means it was proved that the prominences belonged to the sun. The first triumph of the spectroscope at eclipse time was the discovery of helium in 1868, though it was not isolated as an inert gas until 1895. Coronium was discovered in 1869, and even to-day we do not know its physical constitution. Before the eclipse of 1870, Young foretold a sudden change in appearance of the spectrum of the sun

[1] Based on the Penrose Memorial Lecture delivered in Philadelphia on April 22 at the annual meeting of the American Philosophical Society.



Photographed by I. C. Gardner, of the National Bureau of Standards
THE CORONA OF JUNE 8, 1937.

at the time of the beginning of totality, from dark lines on a bright background to the sudden flashing out of bright lines on a dark background. His were the first eyes to see the spectrum of the chromosphere called by him the "flash spectrum," which was first photographed but very imperfectly at the eclipse of 1893. With better and better photographic plates, each eclipse, especially since 1900, has been assiduously observed, distances away from home and difficulty of access being no insurmountable obstacles to the eclipse observer.

The 1937 eclipse will go down in history memorable for three different reasons: first, for the longest duration of totality in more than twelve hundred years (since the year 699); second, for the fact that the eclipse began on June 9 and ended on June 8, the day before it started; and third, in spite of isolation and long distances interested persons could listen in on frequent broadcasts

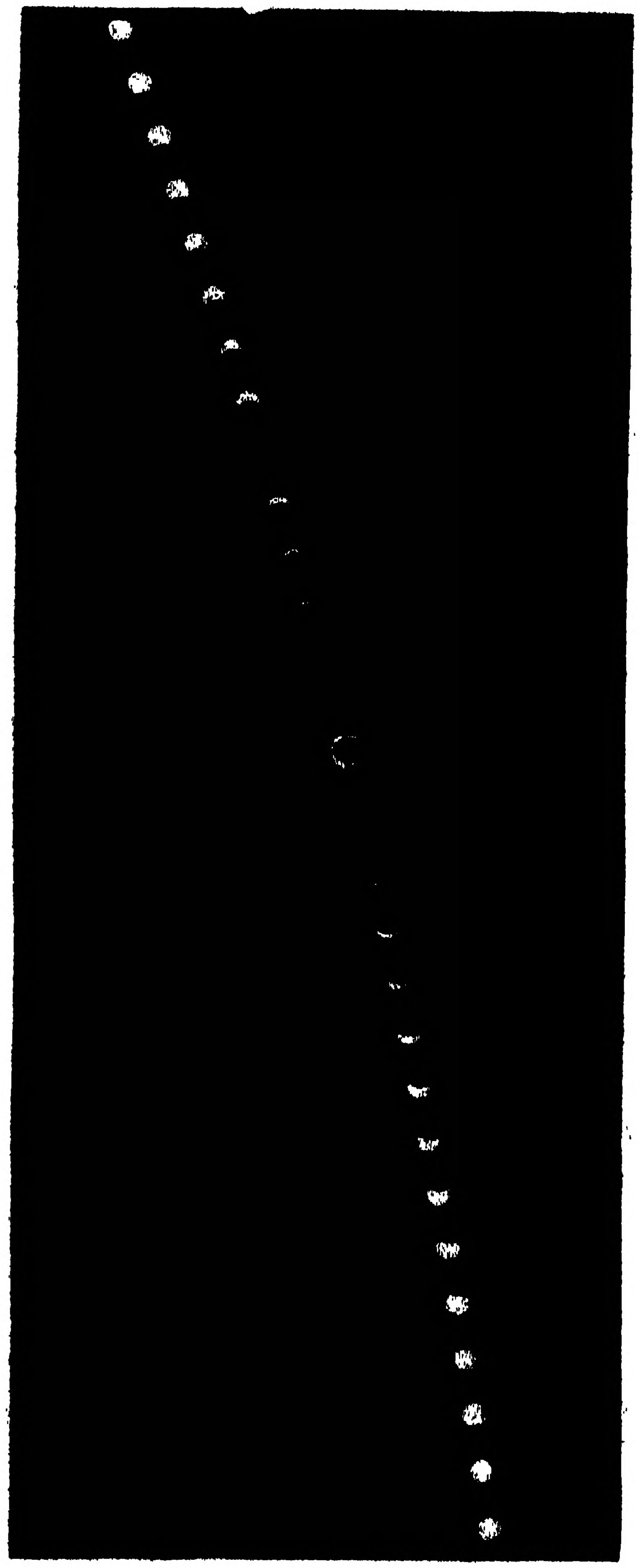
that told of the life on the island and of the preparations over a coast-to-coast network. Two of the broadcasts were specially dramatic, one of fifteen minutes' duration with the phenomenon of the total eclipse at the middle of it, the other a few hours later when the scientific leader of the expedition from Canton Island held a broadcasted conversation with London half way round the world. In the great metropolis was a friend of many years' standing, Alfred Fowler, a distinguished astronomer who in 1893 had made the first photograph of the flash spectrum which since the year 1900 has been my own chief interest at eclipses.

Since the turn of the century, eclipse expeditions to the tropics have fared rather badly from the weather. The writer was a member of a large expedition that went half way round the world to Sumatra to observe on May 18, 1901, an eclipse in the same series with the June 8, 1937, eclipse. With thirteen in the party, this number was unlucky for nine of the expedition, who saw the eclipse entirely eclipsed by clouds. I was one of the fortunate four who photographed the eclipse.

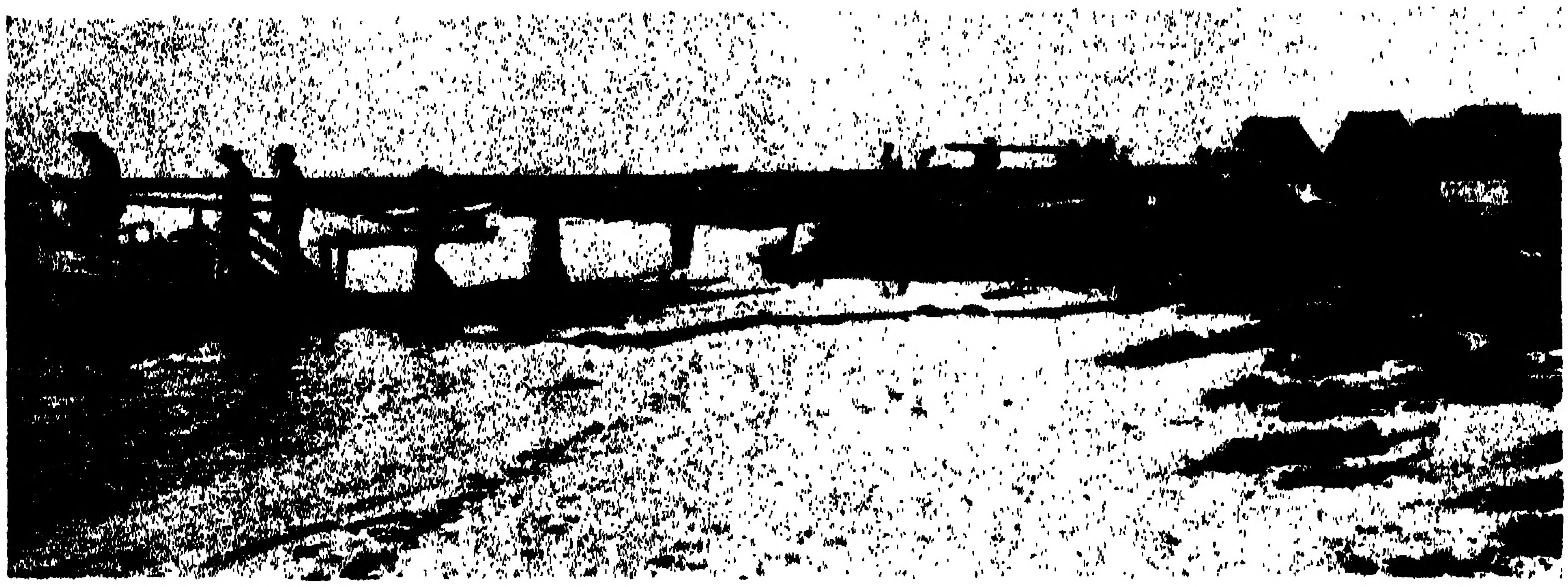
My own second eclipse in the tropics was on October 21, 1930, on "Tin-Can Island" in mid-Pacific. Eclipse day broke with a steady drizzle. First contact was lost in heavy clouds. There seemed no hope whatever—but a quarter of an hour before totality the clouds cleared away beautifully and did not gather again until half an hour after the important 93 seconds of totality had been clicked off.

Luck had been with me in the tropics, two times out of two. It seemed foolhardy to tempt Providence again by going to a third eclipse in the tropics! But an eclipse astronomer must always be an optimist.

It was near the end of January, 1937, that the National Geographic Society through the chairman of its committee on research first proposed an eclipse expedition. It took about a month to work out the preliminary plans and to permit the announcement that the expe-



THE PROGRESS OF THE 1937 ECLIPSE
PHOTOGRAPHS WERE MADE EVERY FIVE MINUTES FROM FIRST CONTACT (BOTTOM). THROUGHOUT THE TWO HOURS THE ONLY CLOUDS THAT INTERFERED ARE SEEN AT THE FIFTH EXPOSURE ABOVE THE TOTAL ECLIPSE (CENTER).



THE UNITED STATES NAVY LANDING SUPPLIES AND EQUIPMENT FOR THE ECLIPSE EXPEDITION.

dition was to be under the joint auspices of the National Geographic Society and the United States Navy.

The scientific leader of the expedition was S. A. Mitchell, director of the Leander McCormick Observatory. He was assisted by: Professor F. K. Richtmyer, Cornell University; Dr. P. A. McNally, director, Georgetown University Observatory; Dr. Theodore Dunham, Jr., Mount Wilson Observatory; Dr. Irvine C. Gardner, National Bureau of Standards; John E. Willis, U. S. Naval Observatory; Charles Bittinger, Washington, and C. G. Thompson, New York City. In addition there were: Richard H. Stewart, staff photographer of the National Geographic Society; George Hicks, announcer for the National Broadcasting Company, and Messrs. Brown and Adams, engineers of N.B.C. The party thus consisted of twelve, eight to take care of the scientific program and four to handle the photography and broadcasting. Captain J. F. Hellweg, U.S.N. (retired), superintendent of the U. S. Naval Observatory, was in charge of the Navy's participation in the expedition.

Before the eclipse plans had been formulated the maneuvers of the U. S. Navy had been planned to take place just about the same time that the expedition expected to depart from Honolulu. It was with regret that the Navy was unable to put at the disposal of the expedition a vessel any larger than U. S. S. *Avocet*, a mine sweeper of about one thousand tons, converted to an aviation tender by having sleeping accommodations for twelve. The *Avocet* was the same size as the *Tanager*, which had been our mother ship at the 1930 eclipse. Then the *Tanager* and the *Ontario* carried the expedition and its equipment 300 miles from Pago Pago to Niuafoou in the Tonga group. This year, with more equipment and greater scientific personnel, the *Avocet* carried the party six times as far as in the earlier eclipse. The twelve of us slept in one room athwartships in size about 15 by 25 feet. Going south from Honolulu we had a following breeze with the result that the heat from the engine room was wafted just abaft to our commodious quarters, where we had about as much privacy as the proverbial goldfish.

After a well-planned broadcast on May 6 lasting from 10:30 to 11:00 A.M. (Honolulu time), in which Governor Poindexter, Admiral Murfin, scientists and Navy officers participated, we were given a grand send-off to the strains of "Aloha" by the Royal Hawaiian band. It was quite thrilling but none the less a little depressing, for we could not know what luck had in store for us.

At daylight on the morning of May 13,

Enderbury Island of the Phoenix group was dead ahead and we could see the "landing place" described in the pilot book. At 8:30 A.M. we were in close to the island and cruised along the west side as far as the landing but found no anchorage with the water close inshore 100 fathoms deep. The duration of totality was 30 seconds longer on Enderbury than on Canton Island on account of a position closer to the center of the moon's shadow path, but in spite of the shorter duration it was much easier to have a successful expedition on Canton Island. The island consists of a narrow strip of coral 400 yards wide surrounding a lagoon, the average height of the island being 10 feet above sea level, the highest point 10 feet greater. There was excellent anchorage at the mouth of the lagoon on the west side of the island, where the prevailing trade winds and the tidal currents would keep the vessel off shore in case the anchor was dragged with no steam in the boilers. On the afternoon of May 13 the first party went ashore. I myself have always believed thirteen a lucky number and so I was quite willing to be a member of a party of 13, to land on the 13th and have 26 days or twice thirteen before the day of the eclipse.

Ashore were found some old timbers from a wreck, which were dragged to the edge of the lagoon and a wharf constructed. With the efficient help of the Navy it was a comparatively simple matter to load the 150 cases of instruments, the 10,000 board feet of lumber and 60 bags of cement into the Navy launches in the quiet waters at the anchorage and put everything ashore on the wharf in

BROADCASTING BIRD VOICES FROM CANTON ISLAND

A BIRD IS IN THE HANDS OF THE SAILOR TO THE RIGHT, AND TO HIS LEFT MAY BE SEEN A CORNER OF THE "MIKE." THE BIRDS HELD BY THEIR WINGS ARE A MAN-O-WAR, AND A BLUE-FACED BOOBY IN THE FOREGROUND.

I. C. GARDNER (RIGHT) AND R. H. STEWART WITH THE CAMERA CONSTRUCTED UNDER THE DIRECTION OF THE FORMER.

the still quieter waters of the lagoon. Twenty tents and a mess tent constituted our homes ashore. Canton Island is at 173° west longitude. Its three degrees of south latitude makes June 21 the shortest day in the year, the sun rising five minutes after six, so that the difference between the longest and shortest days of the year is a mere twenty minutes.

The only trees near us were a half dozen sad-looking coconut palms that would afford no shelter from the blistering tropical sun. In fact, the disintegrated coral reflected the sun's rays so thoroughly that we got a double dose of the sun's heat. However, the temperatures were not high, for the ever-constant trade winds blew over the waters of the lagoon so that the temperatures ranged from 80° F. at night to 85° at midday. The siesta that usually accompanies life in the tropics was not to be ours, for the simple reason that the time ashore was all too short as it was to erect and adjust the instruments. Except for the heat (and that was part of the game) the site was ideal for an eclipse expedition. The instruments were set out along a meridian comparatively close to the edge of the lagoon. Immediately behind were two rows of tents and behind these the mess tent and galley. On the expedition which kept the *Avocet* away from Honolulu for 42 days or six weeks, we ate what was carried by the ship, though on the island we did have fresh fish on two separate occasions.

Afloat and ashore we kept Honolulu time (10½ hours W. of Greenwich). During the weeks of preparation on Canton Island we had the advantage of one hour of daylight saving time. As the sun rose at approximately six o'clock local time, it did not rise until seven o'clock by our clocks, at which hour everybody was

ready to get up without grumbling and go to work. We worked until noon and had dinner and again until late in the afternoon. Before supper at six o'clock we had time to have a swim in the lagoon, the only bath tub for the party ashore. Outside at the anchorage, the waters teemed with fish of all sizes. The waters also teemed with sharks of all sizes. Frequently while the sailors were hauling in a good-sized fish a shark would bite it in two before it could be taken aboard. We have heard it said that sharks are not man-eaters—but possibly that remark refers to sharks in the Atlantic Ocean. Although as scientists we are accustomed to make experiments, yet strangely enough none of us were anxious to make the shark experiment in the Pacific Ocean. Even in the lagoon just off our wharf we caught a 5-foot shark on a line. When it was cut open it had five baby sharks, one of which swam off when put in the water. Perhaps we should not have gone in swimming in the lagoon with so great danger from sharks so close at hand—but we took the precaution of not going far from shore and also of keeping a wary eye always for a disturbing fin.

Ashore there was not much of interest aside from our work except to watch the sea birds, the hermit crabs and the rats. The hermit crabs follow the custom of the tropics and take a siesta in the middle of the day in the shade of a rotten timber or a sheltering rock. At dark they are ready to make off in search of food, for they are the scavengers. At night when lying in our cots we could hear them dragging their borrowed homes, their shells, over the coral of our tent floor. After we had learned to put our shoes and garments out of reach, we could sleep without worrying about the loss of articles of personal use. One morning I found that my one and only tube of tooth paste had vanished. I am a methodical person and carefully screw the cap on the paste after each use. A short search in the tent revealed the tooth paste but rather battered as to outside appearance. Believe it or not, the screw cap was gone! I found it two days later two feet away from the rest of the tube.

With much of work and pleasant companions, time passed very quickly. After dark we had no illumination other than barn lanterns, so we had plenty of time to watch the heavens. Our tents had been pitched so that the opening at noon would be directed away from the sun and hence faced the south. We had a chance to feast our eyes on what is perhaps the most beautiful part of the sky, namely, the Southern Milky Way in the vicinity of the Southern Cross.

On May 26, H. M. S. *Wellington* arrived at Canton Island bringing the New Zealand party of eight, two of whom had worked alongside me at the 1930 eclipse on Niuafoou. I was very glad to renew old friendships. We laid out a meridian for them and helped them orient their instruments; we had them to Sunday dinner when we had roast chicken and in turn they had us to a smoker or two. The American sailors entertained the British tars ashore to a field day, at which there were pie-eating contests, three-legged races, boxing bouts, etc. In return the American sailors were entertained on board the *Wellington* to a social evening.

On eclipse day we were awakened by a loud-lunged sailor at 4:40, though some of the expedition had been up all night in last-minute preparations. It had been clear in the early evening but had clouded up at three in the morning and it was hopelessly cloudy when we emerged from our tents. There was a broadcast at 5:30 A.M., at which time we gave impressions of the weather at earlier eclipses and voiced our fond hopes for clear skies. Although it was densely cloudy, we could still be optimists and could hope for the best. Breakfast was at six o'clock under the light of lanterns,

F. K. RICHTMYER TRAINING HIS ASSISTANTS.

with the clouds broken some but the skies quite bad towards the east. The sun rose about seven in a bank of clouds but with general conditions much improved. A quarter of an hour later the whole sky was clear except for floating clouds here and there. We were in great good luck, for the only cloud over the sun from first contact which came at 7:35 through to fourth contact was a thin one that passed over the sun about five minutes after the precious photographs had all been taken. Throughout the eclipse the sky seemed brilliant. Evidently the combination of thirteens had been the lucky numbers.

The corona was perhaps the most beautiful I had ever seen in all my ten total eclipses. Although a year before the expected time of sun-spot maximum, the corona was of spot maximum type, extending quite uniformly in circular outline to one solar diameter around the dark moon. Beyond there were many streamers and long spikes going off at many angles. These could be traced to about two diameters from the sun's edge, while on one of the photographs taken by Richtmyer the longest streamer was six diameters or five million miles in length. The beauty of the 1937 corona came mainly from the many long spikes. There were some prominences, principally those at seven and eleven o'clock, as they say in the Navy, but none of them were conspicuously large.

The general shape of the corona can be predicted in advance of the eclipse, depending on the sun-spot cycle. Recently it has been found that the "minimum type" of corona, with long equatorial streamers and strong polar brushes, does not occur at the time of minimum of spots but one and one fourth years earlier. Likewise, the corona closest in shape to a circle takes place one and one

fourth years before spot maximum. The eclipse of 1932 took place 1.2 years before minimum of spots, and its shape was the pronounced elongated type. The succeeding total eclipse of 1934 was only 0.2 years after spot minimum, and yet the corona had lost its minimum-type features and much more closely resembled the circular or "maximum-type" corona.

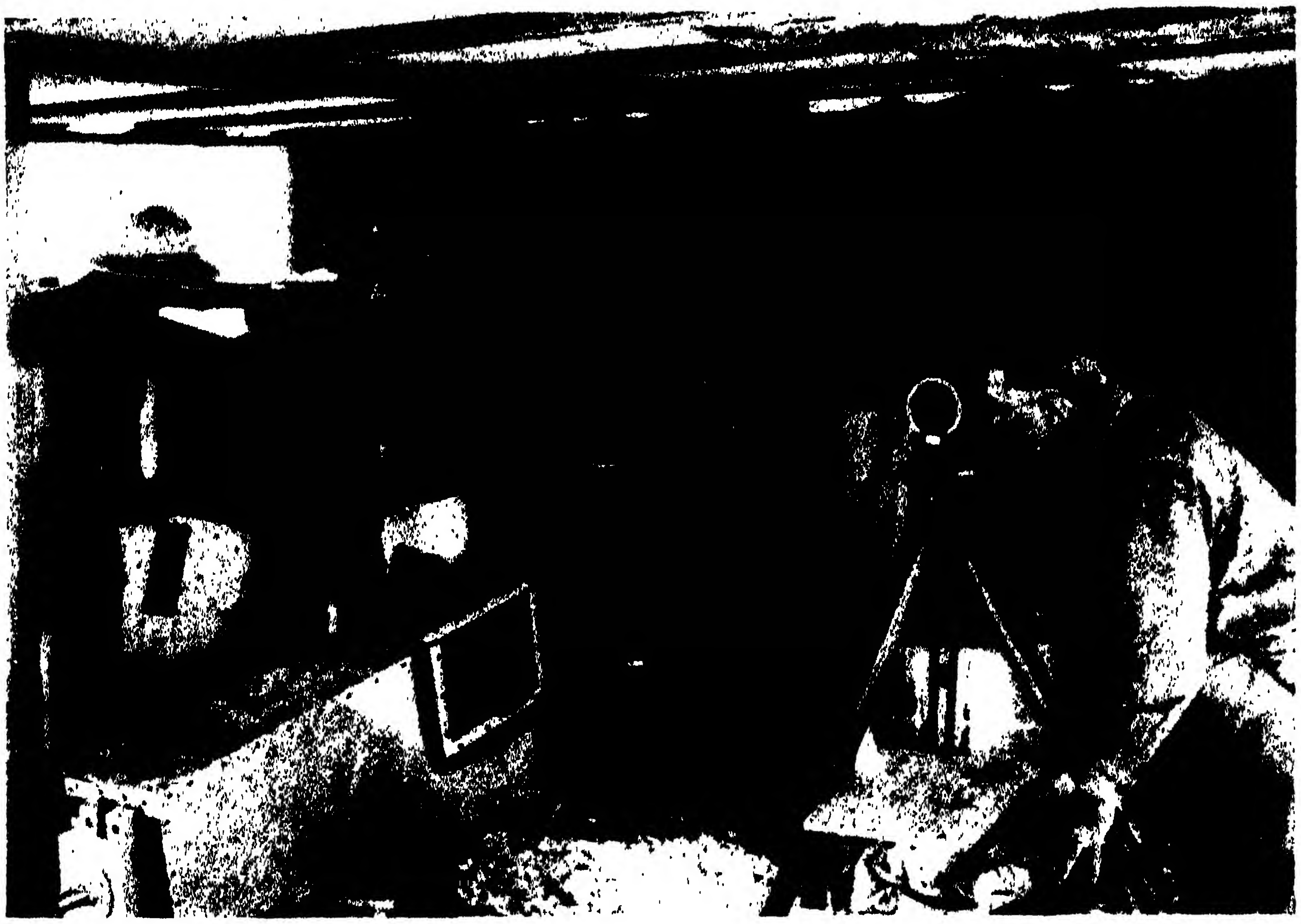
Many attempts have been made to detect motions of coronal materials but without pronounced success. A comparison of Swarthmore and Lick photographs of the 1918 eclipse seemed to indicate motions of the order of 10 miles per second, but at the 1926 eclipse a comparison of coronal photographs made in East Africa and Sumatra revealed that any motions in the corona were no more than one mile per second, or no greater than the inherent errors of measurement. The few spectroscopic measures that have been made seem to indicate motions away from the sun at speeds of 15 miles per second, though the evidence is not very convincing and needs to be verified.

Valuable information regarding details of coronal radiation were secured on Niuafoou in 1930 from large-scale spectra taken with a concave grating without slit when the coronal lines are rings of light and not the customary straight lines one expects in spectra. The spectrograms were compared with the direct photographs of exquisite detail in the corona and also with spectroheliograms taken on four successive days thousands of miles away at Mt. Wilson or Kodaikanal Observatories. All the photographs tell of an intimate connection between coronal streamers and prominences but also that the streamers, on which the shape of the corona more or less depends, are always located near prominences but are not necessarily exactly connected with those prominences which at the time of the eclipses are of the greatest height. The eclipse spectra showed that the details of the coronal structure in the green "coronium" line at 5,303 Å differed greatly from the details found in the red line at 6,374 Å.

In the report of the Commission on Eclipses presented to the International Astronomical Union at its last meeting in 1935, it seemed that we might be on the verge of a fairly complete understanding of the method whereby the light of the corona is diffused and scattered. Grotrian had found that the distribution of energy in the spectrum of the corona is identical with that in the solar spectrum, the dark lines in the spectrum of the outer corona giving fair indication that the light of the corona is scattered sunlight. At the 1932 eclipse, Dufay and Grouiller had shown that the amount of polarization in the corona is entirely independent of wave-length and is a maximum of 26 per cent. at an angular distance 10′ from the sun's limb.

Other observers, however, have come to quite different conclusions. From the two eclipses of 1932 and 1934 Cohn finds that the polarization in the corona is quite different for short and long wave-lengths. In fact, the polarization in the integrated light, in the blue and in the red increases steadily from the sun's limb toward the outer corona, whereas it reaches maxima both in the violet and in the green and then decreases again. At 4′.5 from the sun's limb the polarization is actually independent of wave-length, but at smaller distances in the inner corona the polarization is higher for short wave-lengths than for long wave-lengths. At the 1936 eclipse, Zakharin confirms the conclusions of Cohn that the degree of polarization is different for different regions of the spectrum.

Likewise our knowledge regarding the law of distribution of light within the corona is in a very unsatisfactory state. There are many laws of intensity found by various observers, such as the 2nd, 3rd, 6th, 7th, 8th and such powers as 2.3 or 2.4 of the distance measured either



S. A. MITCHELL PUTTING INTO LINE HIS THREE CONCAVE GRATING SPECTROGRAPHS.

from the center or from the edge of the sun. At the 1936 eclipse, the Polish expedition found that the intensity of the coronal radiation measured from the sun's limb outward diminished more rapidly in red light than in yellow, while the Italian photographs at the same eclipse showed that the intensity in the blue also diminished more rapidly than in the yellow.

In view of much conflicting evidence it is very important that measures both of intensity and of polarization be repeated in different wave-lengths by many different observers. For polarization measures there has come a great simplicity of technique through the application of "polaroid" to eclipse work, which had been done both at the 1936 and 1937 eclipses. At the 1937 eclipse on Canton Island, F. K. Richtmyer secured successful photographs which are now in the process of measurement and reduction.

Accurate values of the total light of the corona have been derived by Richtmyer and by Stebbins in Peru, each using a photoelectric cell. The two results are in good agreement, namely, 53 and 47 per cent., respectively, of the total light of the full moon. From the ten most reliable measures previous to 1937, the average showed the total coronal light 47 per cent. of the full moon.

Measures by illumination meters of the intensity of light of the corona plus illuminated sky have given much conflicting information for the reason that it has been impossible to adequately allow for the effects of sky illumination. In spite of the conflicting evidence, however, some astronomers have reached too hasty conclusions in their attempts to correlate intensity of coronal radiation with sunspot activity. It does indeed seem probable that the inner corona at spot maximum must be brighter than at spot minimum. Moreover, as the inner corona

contributes the greatest part of the energy of the total coronal radiation, we would logically expect that the total energy at maximum of spots would be greater than at minimum. Unfortunately, eclipses come but seldom and there are far too few observations from which to derive any satisfactory correlations.

In spite of many inconsistencies in the results, observers throughout the past fifty years have been in substantial agreement that the total light of the corona is roughly one half that of the full moon, or one millionth that of noonday sun.

In the year 1882 a bright comet was observed near the eclipsed sun, but was never seen before nor since. The corona appeared so bright that attempts were made to photograph the corona without waiting for an eclipse. Attempts followed attempts with every conceivable variety of attack—and failure to achieve results followed failure for fifty years. In fact, it was not until 1930 that Lyot, of the Meudon Observatory, achieved a brilliant success where others had repeated failures. His great triumph resulted from the ingenious arrangement of his telescope to reduce to a minimum the amount of scattered light inside the instrument. A mountain observatory on the Pic du Midi (9,100 feet) and at times very transparent skies permitted photographs of the brighter parts of the corona in full daylight, but he also derived accurate wave-lengths of eleven emission lines of "coronium," three of which at great wave-lengths have not been photographed at eclipses.

In addition to the eleven lines measured, there are twelve other lines in the spectrum of the corona that have been observed by others at many eclipses. Consequently, there is a total of 23 known emission lines. In addition, at the 1936 eclipse two Japanese expeditions publish a total of 11 other lines in the region of between 5,000 and 7,000 A where Lyot's spectra were photographed under the best conditions. These lines are faint and need to be verified by future observations.

It may be said that the corona exhibits three separate spectra: first, the emission spectrum in the inner corona extending to 5′ or 200,000 km from the sun's edge; second, the continuous spectrum (without lines) in the middle corona; and third, the Fraunhofer lines showing feebly in the outer corona. In the continuous spectrum it has been found that there is a band of absorption at wave-length about 6300 which has a greater intensity in the corona than in the photosphere. At the 1936 eclipse the same band was photographed in the spectrum of the light of the sky during totality. The same band appears in the spectrum of twilight, in the spectrum of the night sky and also in the spectrum of the aurora borealis. In accordance with the theory of Störmer that aurorae are caused by corpuscular radiation from the sun, then it must happen that at the time of intense solar activity there would be a strong aurora on the side of the earth turned towards the sun. The band seen in the 1936 spectra needs to be confirmed at future eclipses but it does look probable that it is actually the auroral band which one would expect to be strong near the time of sun-spot maximum.

By comparing wave-lengths east and west, Lyot finds that the inner corona rotates at a speed about equal to that of the photosphere.

In comparing the green and red coronal rings obtained in 1930 on spectra taken with a concave grating and without slit, it was surprising to find how little the lines resembled each other in their structural details or how little either resembled the H and K lines in the chromosphere. It is evident that these two lines can not take their origin in the same atom, or at least, not in the same atom in the same state of ionization.

In spite of many attempts, no further progress has been made in deciphering the source of coronium.

In elucidating the enigmas of the corona much substantial progress has been made, but yet there are many unsolved problems. According to Rosseland, "the corona has stimulated speculation to the breaking point, it being even suggested that there we witness our recognized physical laws set at naught by nature itself." It is evident that the cause of the coronal radiation can not be found in the emission spectrum of coronium, which contributes only a very small fraction to the total energy of coronal light. We must therefore seek the explanation of the mysterious corona in the spectrum of the middle and outer corona.

As the result of many different theories, it is now generally recognized that the electron must play an important rôle in explaining the radiation of the corona. If the continuous spectra is caused by free electrons, then the average thermal velocity of the electron would cause a Doppler effect of the order of ten angstroms which would effectively wipe out all Fraunhofer lines with the exception of the broad wings of the H and K lines. Electron scattering will give an adequate explanation of the absence of dark lines in the inner corona and also is in conformity with the fact that there is little difference in energy distribution between the radiation of the corona and that of scattered sunlight.

In future eclipses there is a great need of carefully designed spectrographs of great speed and large dispersion. At the 1937 eclipse, Dunham had the most powerful spectrograph ever used at an eclipse, for he had virtually a duplicate of the one used with the 100-inch Mt. Wilson reflector. With smaller dispersions we need to compare the intensity distribution of the coronal light with that of the photosphere, and we need more and better spectra that will give the dark lines in the outer coronal spectrum that should be taken under clear skies devoid of water vapor in order that the photographs may verify that the Fraunhofer lines are coronal in origin and do not come from sunlight scattered in the earth's atmosphere.

Lyot has contributed much valuable information to the emission spectrum of coronium, but the outstanding problems connected with the corona will be solved only by observations made at total eclipses. The chief difficulty is that on the average only one minute per year is given to any astronomer to secure his important observations. The next total eclipse to be observed will be on October 1, 1940, visible in Brazil and South Africa.

In recent years the chief contributions from observations made during total eclipses of the sun have had no connection with the corona but have been in two widely separated fields of investigation. In 1919, at the eclipse which was the forerunner in the Saros cycle of the eclipse of June 8, 1937, the whole world was electrified by the confirmation of the Einstein prediction that rays from stars are bent when under the influence of the strong gravitational pull of the sun. Although the splendid observations at the 1922 eclipse seemed to give a complete verification of the Einstein value, it was found by Freundlich from observations at the 1929 eclipse that the deflection at the sun's limb was considerably greater than 1″.75 required by theory and amounted to 2″.24. The chief trouble with eclipse plates is that the same stars which furnish the relativity displacements must also give the scale of the photographs. The stars at the 1929 eclipse were badly distributed around the sun, as is seen by the fact that out of a total of 18 stars used to measure the relativity effect there were 17 stars located on one side of the sun and only one star on the other side, with the result that

THE MOST POWERFUL SPECTROGRAPH EVER USED AT AN ECLIPSE
T. DUNHAM, JR. AND C. G. THOMPSON ADJUSTING THE MOUNT WILSON INSTRUMENT.

scale value was poorly determined. A discussion by Trumpler of all observations at the eclipses of 1919, 1922 and 1929 gives the relativity deflection reduced to the sun's edge as $1''.79 \pm ''.06$.

In view of the discordant results from the 1929 eclipse, it is evidently necessary to repeat the observations, devoting special care to a more accurate determination of the scale value of the photographs. Unfortunately, this obvious recommendation can with difficulty be put into effect for the reason that the star fields at total eclipses in the next twenty years do not contain a sufficient number of bright stars. In spite of these drawbacks, the British astronomers are planning to again test the Einstein deflection as a part of a very extensive program of observations for the 1940 eclipse.

The sun is the nearest of the fixed stars, and it is the only star which permits a detailed study of conditions in the outlying atmosphere. As these conditions have gradually become understood in the sun they have furnished the method of interpreting many outstanding stellar problems. Perhaps the greatest contribution in recent years from eclipse observations has been the rather perfect knowledge of heights to which the gases of the chromosphere extend above the surface of the sun. Photographs of the flash spectrum taken without a slit give a spectrum of curved arcs from which heights are immediately derived. From these heights furnished to

Saha fifteen years ago he was able to compute the conditions of temperature and reduced pressures that causes an atom to lose an external electron and become ionized. His theory of ionization coupled with increased knowledge of the structure of the atom has made the past fifteen years the most prolific and most exciting years in the whole history of astronomy.

All the prominent lines in the spectrum of the sun have been assigned to multiplet groups with known excitation potentials measured in electron-volts; the arbitrary intensity scale of Rowland has been submitted to calibration tests which have revealed that the intensities depend on the number of atoms engaged in the formation of the spectral lines. From the weakest iron lines perceptible in the solar spectrum to the strongest the number of atoms involved increases about one million times.

A person with no knowledge of the theory underlying multiplet groups would not advance very far in the practical operation of correlating heights from eclipse spectra with intensities before the fact would be forced upon his attention that the lines of greatest intensities generally reach the greatest heights, and moreover for any element considered, the intensities and heights are greatest for lines of lowest excitation potential.

MITCHELL AND A BABY MAN-O-WAR BIRD.

THE MAN-O-WAR OR FRIGATE BIRD EXHIBITING HIS BRILLIANT TURKEY-RED POUCH.

Fascinating work on sun-spots was started by Evershed and carried through to completion by St. John, using the 150-foot tower telescope of Mt. Wilson. With the slit of the spectrograph placed across the image of a spot it was found that the wave-lengths in the penumbra of the spots were different from the values at the center of the sun. These "Evershed displacements," as they are called, affect practically all lines, but the amount depends on the intensities of the lines. The heights derived from eclipse spectra furnish the explanation. The layers closest to the sun's surface have a motion of translation out of the spot at the rate of 2 km per sec. At greater and greater heights this motion becomes less and less in amount. At a certain level, the outward motion of vapors ceases and at still greater heights

the motion of translation is in the opposite direction into the spot. At the maximum heights reached by the H and K lines of Ca^+, the speed of motion into the spot is 3.8 km per sec.

The Evershed effect shows that there is a circulation of gaseous material in the neighborhood of sun-spots or, in other words, that each sun-spot is a great vortex.

One consequence of the Einstein theory of relativity is that wave-lengths in the sun must be greater than in the laboratory, the amount of shift to the red depending on the wave-length. The best element for determining the red shift in the sun is iron. From the discussion of abundant material coupled with a knowledge of heights from eclipse spectra it is evident that the relativity shift is most certainly present, but in addition there are systematic differences between the effects shown by the strong and the weak iron lines, the strong lines being those that extend to great heights in the sun. The systematic differences are most readily explained as a Doppler shift caused by a circulation of vapors in the sun's atmosphere. On account of the higher temperatures and higher pressures near the photosphere, the solar activity causes the *Fe* atoms to ascend through the medium of thousands of weak lines of high excitation potential. In the upper reaches of the chromosphere under reduced pressures some of the atoms lose an external electron and become ionized. Later the atoms descend from their maximum heights and in their descent some of the atoms gain an external electron and again become neutral. According to this interpretation, in a direct photograph of the sun showing a mottled surface, the atoms ascending exhibit themselves over the small bright granules and the descending ones over the larger dark interspaces, the observed effect being an integrated one.

In the celestial laboratory of the sun the astronomer has available for his researches very high temperatures and very minute pressures far transcending the conditions available to the physicist in terrestrial laboratories. As the result of a knowledge of the structure of the atom, Henry Norris Russell and others have assigned practically all the strong lines in the solar spectrum to multiplet groups and have ascertained the energy, measured in electron-volts, necessary to produce the spectral lines. From a knowledge of the multiplet intensity formulae it has been possible to learn the relative numbers of atoms involved in the transfer from one energy level to another in the production of absorption or emission in the sun's atmosphere.

The heights determined from eclipse spectra to which the solar gases extend in the chromosphere have permitted many important correlations. These correlations are shown by the dozen lines of a multiplet involving strong *Fe* lines,[2] where 100 times as many atoms are active in producing the strongest line in the multiplet at wave-lengths 3,820 Å as go to form the weakest line at 3,940 Å. Even within a single multiplet, the heights found directly from the flash spectrum or indirectly from the Evershed effect in sun-spots, are not constant but are greatest in size for the strongest lines and therefore those which extend to the greatest heights and involve the greatest number of atoms.

Again, a knowledge of the heights from the flash spectrum to which the various lines in multiplets are observed combined with information from the number of atoms involved gives important knowledge regarding the density distribution of various elements in the lower chromosphere. The results seem to indicate that turbulence and not radiation pressure is responsible for keeping the different elements so well mixed.

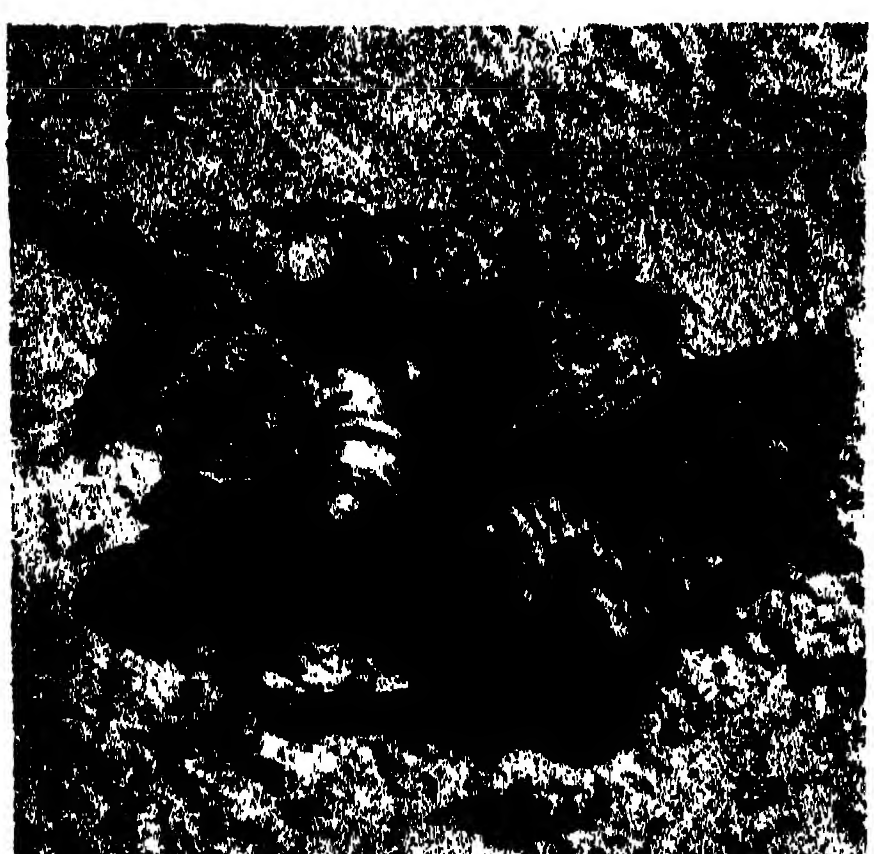
[2] "Eclipses of the Sun," 4th Edition, page 348.

From the flash spectrum there has been determined the relative abundance of various elements and the results from the chromosphere have been compared with the abundances found in the sun's reversing layer, in stellar atmospheres, in the earth's crust and in stony meteorites. It is shown that within errors of observation the composition of all samples are alike, with the exception that hydrogen is conspicuously deficient in the earth's crust and in meteorites and is probably much more abundant in the chromosphere than in the reversing layer.

The eclipse of 1936 was observed throughout Siberia and Japan with much interference from clouds while the 1937 eclipse had clear skies everywhere. In 1936 the British expedition in Japan under the direction of Stratton obtained excellent results in spite of many clouds, while in Siberia the Harvard-Massachusetts Institute of Technology expedition under the guidance of Menzel secured carefully standardized and calibrated spectra with large dispersion in the spectral region 3,200–10,000 Ångstroms. In Siberia, Williams found 12 new lines in the chromosphere in the infra-red with wave-lengths between 9,000 and 10,049 Å. He also photographed eight lines of the Paschen series of hydrogen. At the 1937 eclipse on Canton Island, Dunham secured spectra of the chromosphere and corona with large dispersion and jumping-film. Mitchell obtained spectra with three concave gratings without slit. In the infra-red with the Allegheny grating he photographed the strong calcium triplet and also 25 lines of the Paschen series of hydrogen. Also he photographed the strong coronium line at 7,892 Å., this line having been discovered in 1925 by Curtis and Burns using the same grating.

A SCENE ON CANTON ISLAND

SEA-BIRDS RESTING IN THE SAD-LOOKING COCONUT TREES. ON THE PALM TO THE LEFT WE FOUND A NOTICE STATING THAT A YEAR PREVIOUSLY THE ISLAND HAD BEEN TAKEN OVER IN THE NAME OF HIS MAJESTY, KING EDWARD VIII.



HERMIT CRABS ON CANTON ISLAND

IN THEIR BORROWED SHELLS EATING COCONUT.

At the 1936 eclipse from spectra taken outside of totality, Royds, of the British expedition, found that the red shift at the sun's limb is the same in amount inside and outside an eclipse, thus ruling out the possibility that scattering in the earth's atmosphere is the explanation why strong and weak spectral lines show different relativity shifts. In the same expedition, Thackeray finds that the in-

tensities of lines in the Balmer series of hydrogen are in close agreement with the theory of Menzel that the hydrogen lines owe their intensities to some form of excitation in addition to straight electron capture. From the 1937 eclipse Mitchell finds a similar agreement for the intensities of the Paschen series of hydrogen.

Menzel and others at Harvard have published valuable results from the 1932 spectra. Information is given about multiplet intensities and density gradients, self-reversal of hydrogen lines and the general theory of curves of growth and self-reversal of emission lines. Mitchell has nearly ready for publication a discussion of the October 21, 1930, eclipse which will give a redetermination of heights and the density distribution of gases in the chromosphere.

On account of the great activity in recent years of eclipse observers, particularly the American and British, most of the problems have been cleared up that might be attempted by interested amateurs with moderate equipment. There are many mysteries still connected with the corona, with the chromosphere and with the relativity displacements. For instance, from spectra taken at the 1936 eclipse it was found by Thackeray that the emission lines of neutral metals show an unexplained displacement to the violet relative to limb absorption. The emission lines in the chromosphere, if secured with excellent definition, can give valuable information about line profiles which in turn will give further information about the structure of the atom and the mechanism whereby lines in spectra are produced.

In planning for future eclipses, the British have a great advantage over us in the United States, for the reason that our British cousins see each other very frequently at the monthly meetings of the Royal Astronomical Society. With us in the United States, eclipse expeditions become possible only when some interested person is able to raise the rather large amount of money necessary, while in Great Britain the expeditions are handled more efficiently by the Joint Permanent Eclipse Committee organized under the auspices of the Royal Society and Royal Astronomical Society.

GEOLOGY OF SOIL DRIFTING ON THE GREAT PLAINS[1]

By Dr. M. M. LEIGHTON

CHIEF, ILLINOIS STATE GEOLOGICAL SURVEY

I

No subject is more important to mankind than that of husbanding natural resources. Among natural resources, none is more important than soils. Directly or indirectly they provide us with food; their well-being determines our pleasure and comfort; their fixity—or lack of it—has profound effects on our health. Without soil in virtually stable condition civilization can not exist.

All this is everyday knowledge; to some degree it has been apparent for many centuries. But to know is one thing; to act is another. As Sears[2] has shown, human settlement and land use have led, without significant exception, to wholesale wastage of soils. This waste has gone so far that the need for conservation is immediate and pressing; it challenges any enlightened people. Even in the most fertile areas of new countries such as ours, the natural productive capacity of the soil has been greatly reduced by prevailing methods of grazing and farming. This reduction has dollars-and-cents importance. It also presents a grave problem which affects our national future.

The drifting of soils by wind is one very serious phase of the matter. In the Great Plains, our once-wild West, drifting already is a menace to soil resources of the great wheatlands. It is almost as threatening in grazing regions. Travelers who cross the Panhandle of Texas, the sage plains of Wyoming, or the grass lands of Montana will see broad stretches whose value is sinking to almost nothing as winds carry soil away.

Spectacular and overwhelming as it is in the Great Plains, soil drifting is important in even the Central Lowlands. During dry seasons, strong winds pile ridges of black, fertile soil along fences and hedgerows of Illinois and Iowa. Flat stretches of plowed land and the plowed brows of slopes suffer alike from air currents, which first carry and then deposit the material in those ridges. Effects may seem trifling during a decade, appearing negligible to the average layman. But their cumulative results will become disastrous unless intelligent practices reduce drifting until it corresponds to the natural rate of soil renewal.

Soil drifting is a wide-spread process, affecting many different types of land. In North America, however, it has specially characterized the region which we term the Great Plains. With that region this symposium deals. My first purpose is to describe geologic conditions of the Plains which favor or control dust storms of the present. I then shall deal with dust storms of the past, in so far as they have lessons for us. Finally, I shall discuss those principles which, from a geological viewpoint, seem specially significant to any sound program of soil conservation.

II

The Great Plains have long been recognized as a wide belt of high country which slopes eastward from the Rockies to the Central Lowlands. Popularly, the name Great Plains is associated with monoton-

[1] Presented in a symposium on the "Scientific Aspects of the Control of Drifting Soils," Denver meeting of the American Association for the Advancement of Science.

[2] P. Sears, "Deserts on the March." Norman, Univ. Oklahoma Press, 1935.

ous landscapes, short grasses and rainfall of less than 20 inches. In general this conception is valid to-day. The Plains contrast sharply with the prairies or "long-grass country" which bound them on the east.

That boundary is indicated in Fig. 1. Throughout much of its length, it is marked by low, eastward-facing escarpments which are continuous in some places, ragged in others and in some places have been transformed into low belts of hills. In Nebraska and South Dakota, however, this boundary is indefinite. From elevations of 1,200 to 1,500 feet along this eastern border, the land rises to heights of 4,000 to 5,000 feet in its western belt, called the High Plains. Streams which originate in the mountains flow eastward and southeastward across the sloping country to the Mississippi and the Gulf of Mexico. Through long ages, these streams and their tributaries have cut valleys, transforming the surface into a landscape which is much more irregular than it generally seems. Only the Llano Estacado and uplands near the Kansas-Colorado boundary remains as extensive, level areas almost untouched by erosion (Fig. 2). The former comprise 20,000 square miles whose surface has been called "as flat as any land surface in nature."[3]

Except in regions where crystalline rocks reach the surface, both the Great Plains and the Central Lowlands are underlain by sediments. In the Lowlands these stratified rocks may be thin: there are places in South Dakota and Minnesota where they amount to less than 100 feet. Throughout most of the Plains, however, sediments are thousands of feet thick, include many kinds of rock and are grouped into formations of many different ages. These formations outcrop in a narrow belt near the mountains and over great areas in Texas, Oklahoma and

[3] N. M. Fenneman, "Physiography of Western North America." New York, McGraw-Hill, 1931.

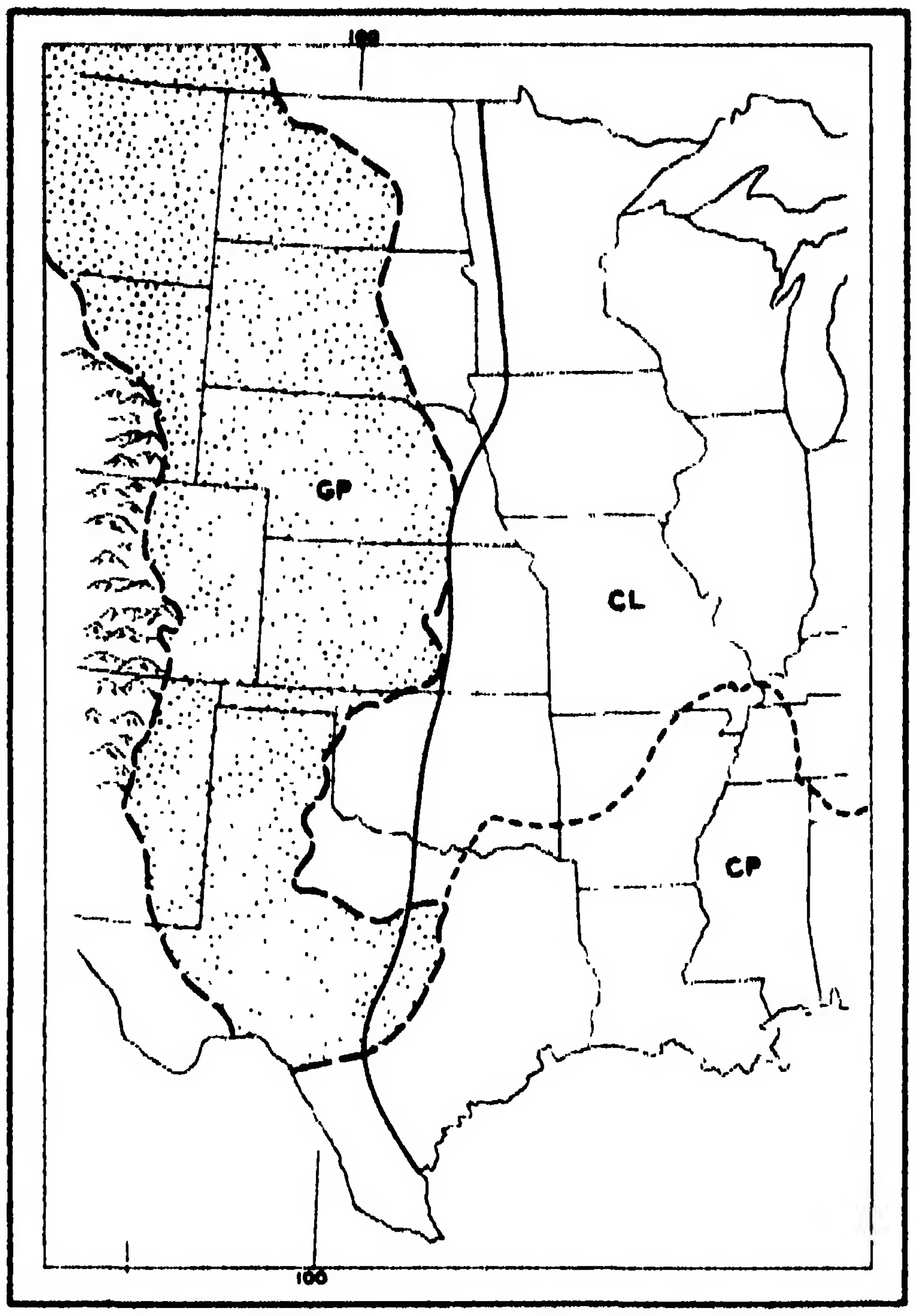
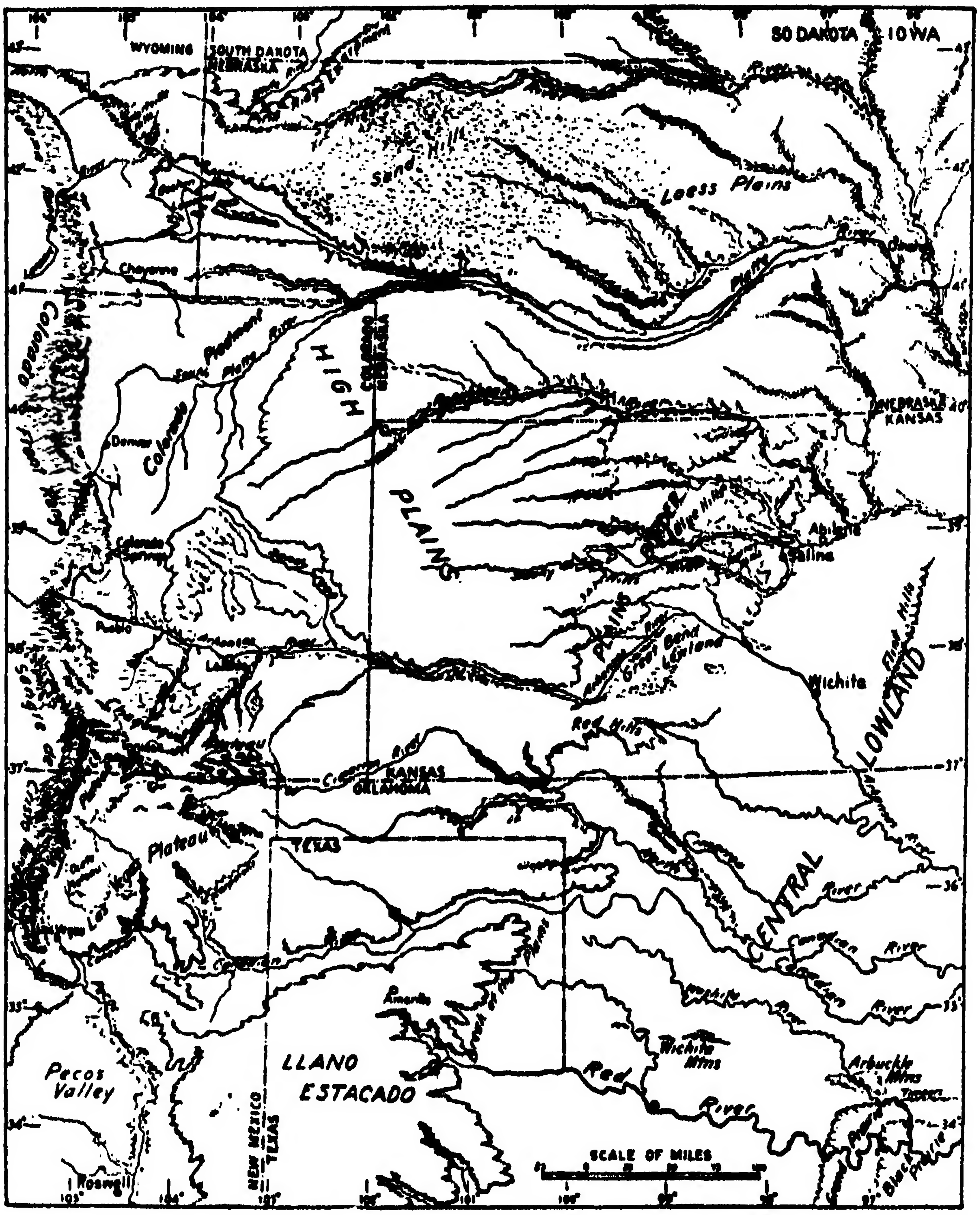


FIG. 1. THE GREAT PLAINS OF THE UNITED STATES

SHOWN BY THE DOTTED AREA (GP). EAST OF THEM LIE THE CENTRAL LOWLANDS (CL) AND THE WESTERN PART OF THE COASTAL PLAIN (CP). THE OZARK–OUACHITA REGION IS NOT INDICATED ON THIS MAP. WEST OF THE PEDOCAL–PEDALFER BOUNDARY (UNBROKEN LINE), LIME ACCUMULATES IN THE SOIL, COMMONLY FORMING CALICHE. (AFTER FENNEMAN AND ATLAS OF AMERICAN AGRICULTURE.)

Kansas, as well as other Plains states, and these outcrops have provided material for extensive areas of soil. The pre-Tertiary strata (those which are more than 60,000,000 years old) have been bowed downward into a basin-like structure whose rocks dip steeply eastward near the mountains but have gentle westward dips on the east side of the basin. Their variations in hardness, as well as their structure, are expressed in the remarkable linear, subparallel escarpments and ridges of eastern Kansas and in steep, high "hogbacks" near the Rocky Mountain front near Boulder, Denver and Colorado Springs. Most of these



Courtesy Mc-Graw Hill Book Co.

FIG 2. CENTRAL PART OF THE GREAT PLAINS

SHOWING THE HIGH PLAINS, LLANO ESTACADO AND THE SAND HILLS. A BROKEN SERIES OF ESCARPMENTS AND HILLS DIVIDE THE PLAINS FROM THE CENTRAL LOWLANDS. DRAWN BY GUY-HAROLD SMITH.

tilted rocks are resistant, but some of the Cretaceous shales which outcrop in Colorado and Wyoming, as well as Triassic "red beds" of the Texas-Oklahoma panhandles, yield readily to erosion by the strong, turbulent winds that are common in those areas.

The older and more indurated strata are popularly called bedrock (BE of Fig. 3). In large areas of western Texas, the panhandle of Oklahoma and western and central Kansas, and in most of Nebraska, the bedrock is covered with relatively young, unconsolidated sediments (TE in Fig. 3). These are the Tertiary deposits, which were washed from the rejuvenated Rocky Mountains and deposited on the Great Plains. Erosion has carved them into hills and valleys and reduced them to remnants along their fringing borders. Throughout considerable areas the surface soils have been made from them. In some places both the soils and some of the parent deposits are readily subject to

wind erosion, especially where they are sandy or silty.

Other very extensive areas are covered with loose, incoherent deposits of wind-blown silt whose origin dates back thousands rather than millions of years. These are the loess deposits of northern and western Kansas, eastern and southern Nebraska; they also extend over large parts of Iowa, Missouri, Illinois, and adjacent territory (L in Fig. 3). As we shall find, the loess consists of old, wind-transported and wind-laid dust deposits which were formed at various times, chiefly during the Glacial Period. The soils of these areas have been made from loess.

In the northwestern part of Nebraska, an area of dune sand, amounting to about 24,000 square miles, is known as the "Sand Hills" (S in Fig. 3). Lugn,[4] of the Nebraska Geological Survey, states:

> The dune sand is the material left behind after the fine silt and clay had been sifted out by wind action and carried eastward and southeastward to become the yellow and yellow-gray loess, which was spread over a fan-shaped area of tens of thousands of square miles south and east of Nebraska and areas farther eastward.

There are other, though smaller, sand areas in Colorado, Kansas, Oklahoma and Texas. Some or all of them may also have contributed material for loess deposits bordering these tracts.

In eastern North Dakota and South Dakota, as well as most of Minnesota and Wisconsin, north-central Iowa, northeastern Illinois and northern Indiana, most of the soils have been made from pebbly and stony glacial drift. In certain places, as in the Red River Valley of the North, the drift has been reworked into lake silts, laid down in glacial Lake Agassiz and neighboring bodies of water. Elsewhere it lies much as melting glaciers left it. The boundary of the drift area (GL) shown in Fig. 3 does not mark the greatest extent of glaciation in the Mississippi Valley, but it essentially limits the area of drift that is free from loess. The oldest drift sheets, which extend into the southern part of Illinois, northern Missouri, northeastern Kansas, and eastern Nebraska are buried beneath loess deposits.

The fringe of deposits along the Gulf of Mexico, shown as CO in Fig. 3 are of marine origin. Alluvial deposits (AL) are fairly wide-spread along the major valleys, but they are mapped here only along the lower Mississippi.

III

The chief sources of recent dust storms are areas within the High Plains and in

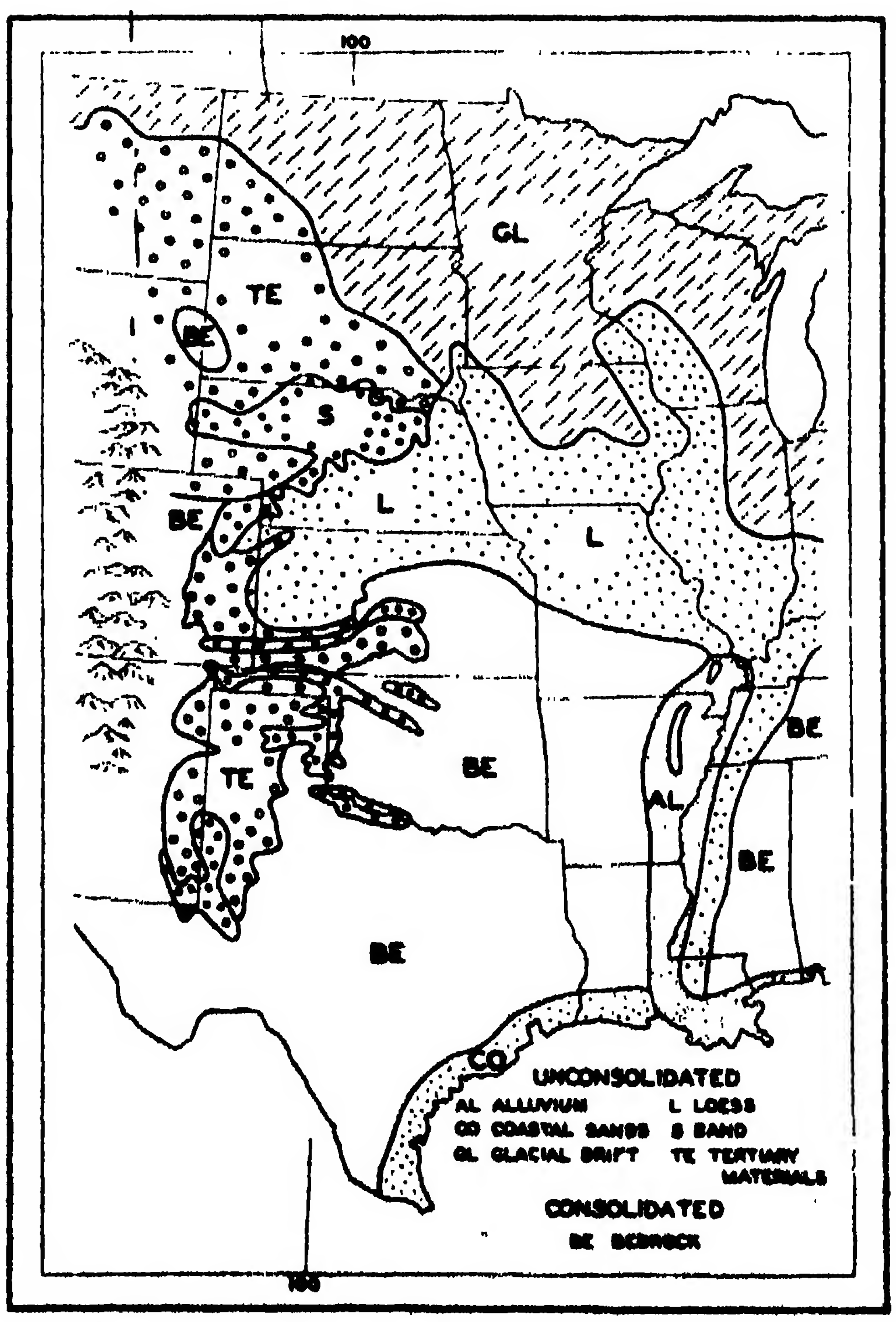


FIG. 3. PARENT SOIL MATERIALS IN THE GREAT PLAINS AND PART OF THE CENTRAL LOWLANDS. AREAS OF "BEDROCK" (BE) CONTAIN FORMATIONS OF MANY DIFFERENT AGES, KINDS AND DEGREES OF HARDNESS. OTHER SOIL-FORMING MATERIALS ARE RELATIVELY UNCONSOLIDATED AND VARIED IN ORIGIN AND CHARACTER.

[4] A. L. Lugn, Nebraska Geol. Survey, *Bul.* 10: 161–162, 1935.

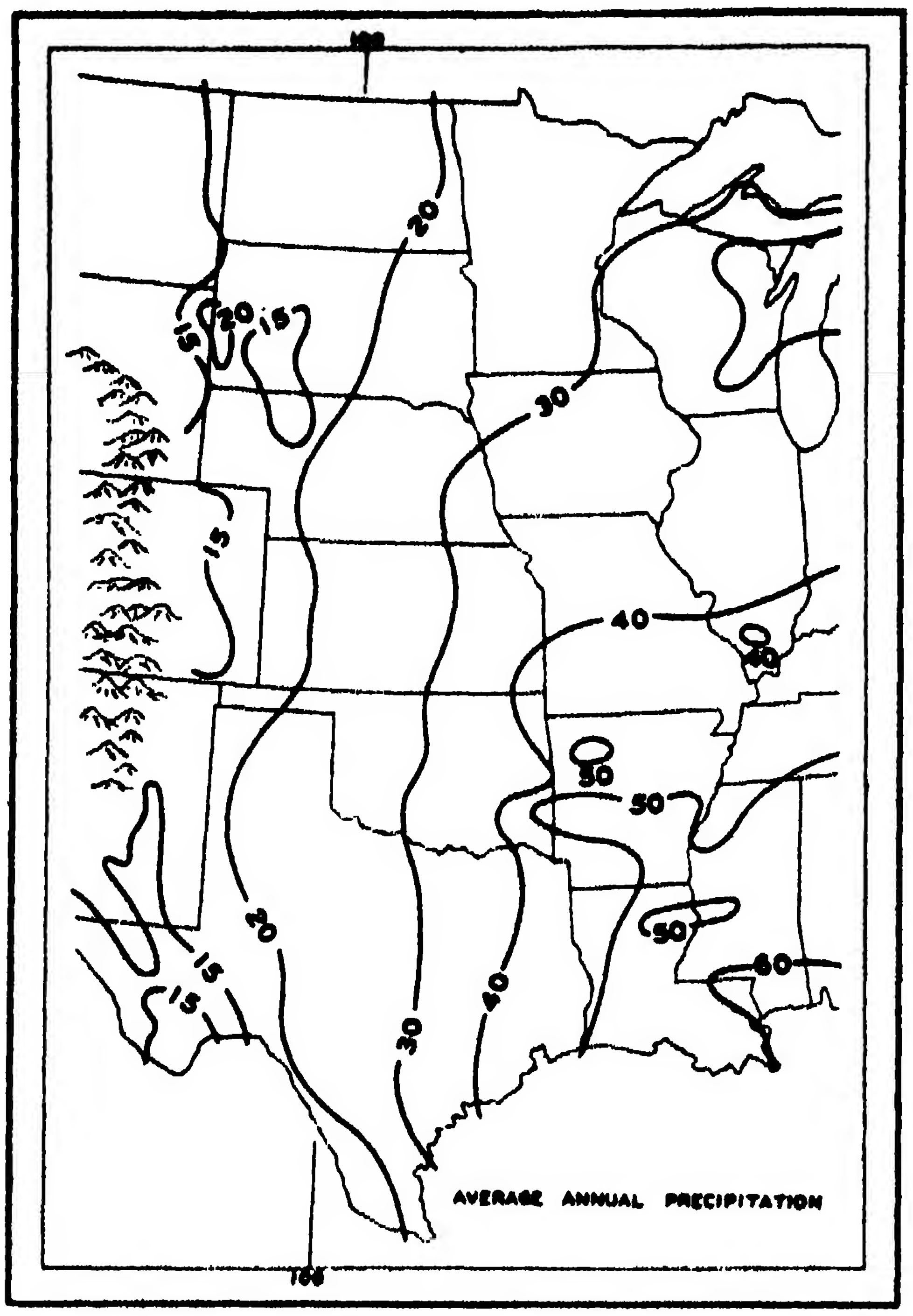


FIG. 4. AVERAGE ANNUAL PRECIPITATION

OF THE GREAT PLAINS AND PART OF THE CENTRAL LOWLANDS AND COASTAL PLAIN. (ADAPTED FROM ATLAS OF AMERICAN AGRICULTURE.)

regions just east of them. Fig 4 shows that the High Plains lie on the dry, lee side of the Rocky Mountains, from which they are separated by the rough Colorado Piedmont. The climate of both regions belongs to the dry, continental type, in contrast to the moist, continental climate of the Mississippi Valley states. According to records of the U. S. Weather Bureau, summarized in the Atlas of American Agriculture, the average annual precipitation throughout most of the High Plains ranges from 15 to 20 inches. In the larger part of the upper Mississippi Valley it is 30 to 40 inches, while 50 to 60 inches of rain fall on the lower Mississippi states. Even in March, April and May, which are moist months, precipitation on the High Plains is almost half what it is in the upper Mississippi Valley. Crop production west of the 100th meridian therefore requires either irrigation or dry-farming methods.

TABLE SHOWING AVERAGE WARM-SEASON EVAPORATION OF THE GREAT PLAINS. (AFTER ATLAS OF AMERICAN AGRICULTURE)[5]

Station (south to north)	Av. total Apr.–Sept. (inches)	Length of record (years)
Texas		
Amarillo	52.71	11
Big Spring	59.00	3
Oklahoma		
Woodward	49.52	4
Kansas		
Colby	39.91	4
Garden City	52.85	10
Nebraska		
Mitchell	38.45	7
North Platte	43.65	11
South Dakota		
Ardmore	38.59	5
Newell	37.00	10
North Dakota		
Dickinson	31.79	10
Hettinger	32.77	7
Mandan	33.30	5
Williston	33.11	8

Low precipitation here is accompanied by notably high evaporation. The average warm-season evaporation, according to the Office of Biophysical Investigations, U. S. Department of Agriculture, ranges from 59 inches at Big Springs, Texas, to 33.3 inches at Mandan, North Dakota. Other data for points most of which are west of the 100th meridian are given in the accompanying table. It indicates that winds of the High Plains are drier than those of more humid areas to the eastward, and that the evaporation is greater to the south than to the north. Fig. 5 shows that, on the average, they also blow faster. These strong, dry winds intensify the aridity caused by light precipitation. They therefore limit vegetative cover, producing biologic as well as climatic conditions which favor the drifting of soil. When winds become very strong—Joel[6] records velocities of 40 to 65 miles at Amarillo, Texas—only soil which has very effective cover can resist the impetus to move.

[5] "Atlas of American Agriculture," U. S. Dept. Agriculture, 1936.

[6] A. H. Joel, U. S. Dept. Agriculture, *Tech. Bull.*, 556, 1937.

IV

Rainfall conditions soil movement, and it changes the soils themselves. East of the solid line in Fig. 1, precipitation exceeds 30 inches and evaporation is moderate, whereas to the west rainfall is lighter and evaporation is greater. In the former case, ground water carries dissolved lime carbonate away, producing what are called pedalferic soils. West of that boundary, lime accumulates a few feet or inches below the surface, forming deposits which locally are called "hard-pan," but are better known as caliche. Such accumulations are dominant, though not universal, and the soils which they characterize are distinguished as pedocalic. Such soils have lost less mineral matter by solution than have those of eastern humid belts. Where (or when) moisture is adequate, pedocalic soils support rich vegetation and contain much organic matter. Those which lack moisture have less organic material, but crops which some of them raise under irrigation prove the abundance of nutritious minerals in them.

Lugn[7] has studied the effect of wind upon the High Plains. He says:

> Loess materials at different times have been derived from exposed Cretaceous shale areas in Colorado and Wyoming, and also from Tertiary High Plains areas in Colorado, Wyoming, and western Nebraska. Recent dust storms have produced blow-out depressions, a number of feet deep and many acres in extent, in exposed Cretaceous and Tertiary formations, especially in South Dakota, western Kansas and eastern Colorado.
>
> Blow out depressions, still mostly undrained, as much as 40 or more feet deep and up to 2 square miles or more in extent, have been formed by wind action in the past, in the exposed Tertiary silty and sandy beds of the High Plains tableland areas of western Nebraska and adjoining areas. McKin has reported such depressions on the Pine Ridge table in northwestern Nebraska. The writer also has observed them on the Pine Ridge, on the Box Butte table, and on the Cheyenne table in western Nebraska, and on the high table south of the Lodge Pole Valley in Nebraska and Colorado.

Lugn[8] ascrcibes the red dust which fell at Lincoln, Nebraska, during the night of April 29, 1933, to the "red beds" of the Triassic and Permian of the Texas and Oklahoma panhandles, western Oklahoma and southern Kansas. The weather map for that date indicates strong and southwesterly winds in Kansas. Lugn also refers the dust carried by the storm of March 20 to 22, 1935, to southeastern Colorado, where eolian blow outs, sand dunes, and dust hummocks were forming. Finally, he says that recent winds in the Sand Hills Region have "drifted considerable quantities of fine and very fine sand eastward from the main area of sand hills out over the somewhat older true loess."

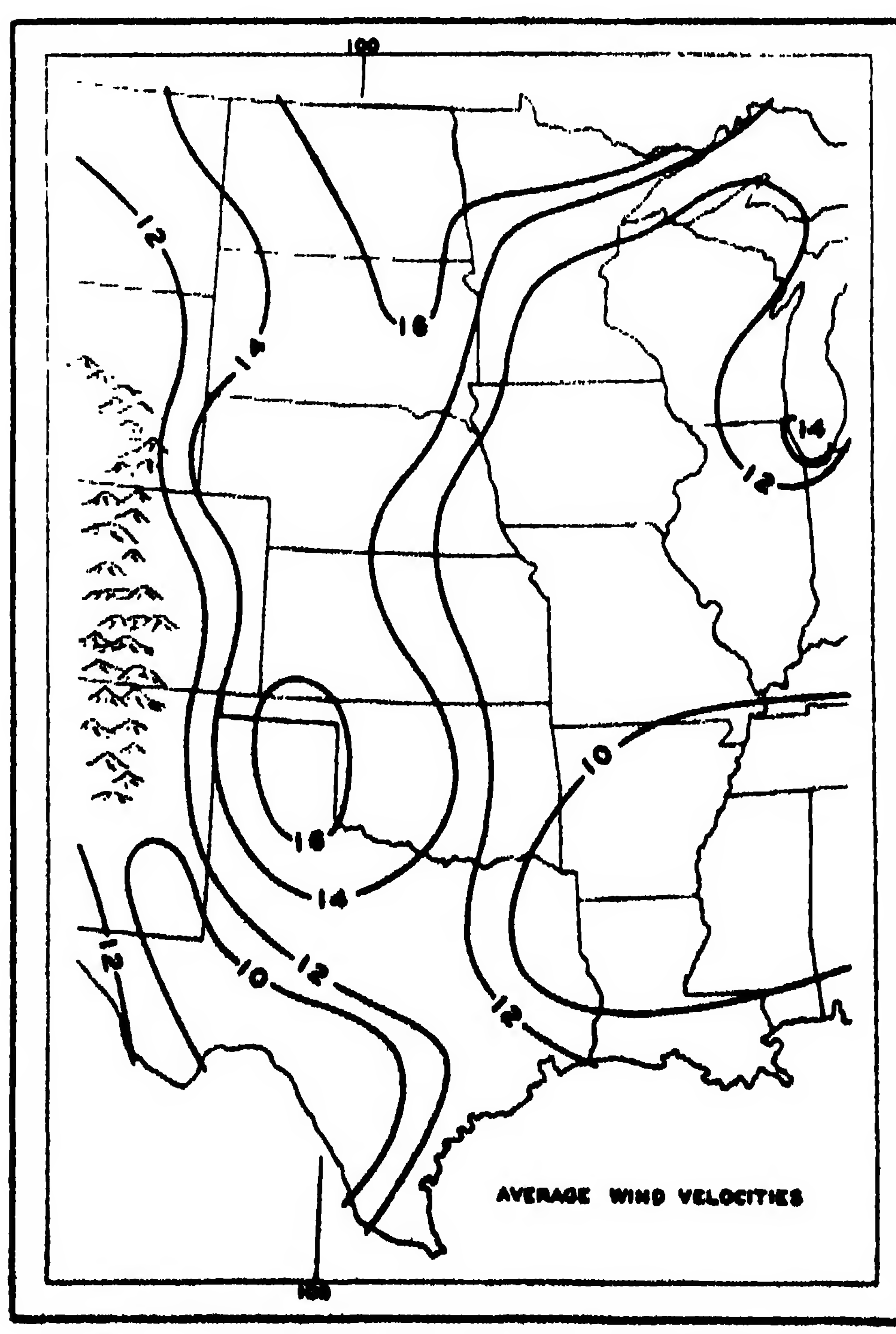
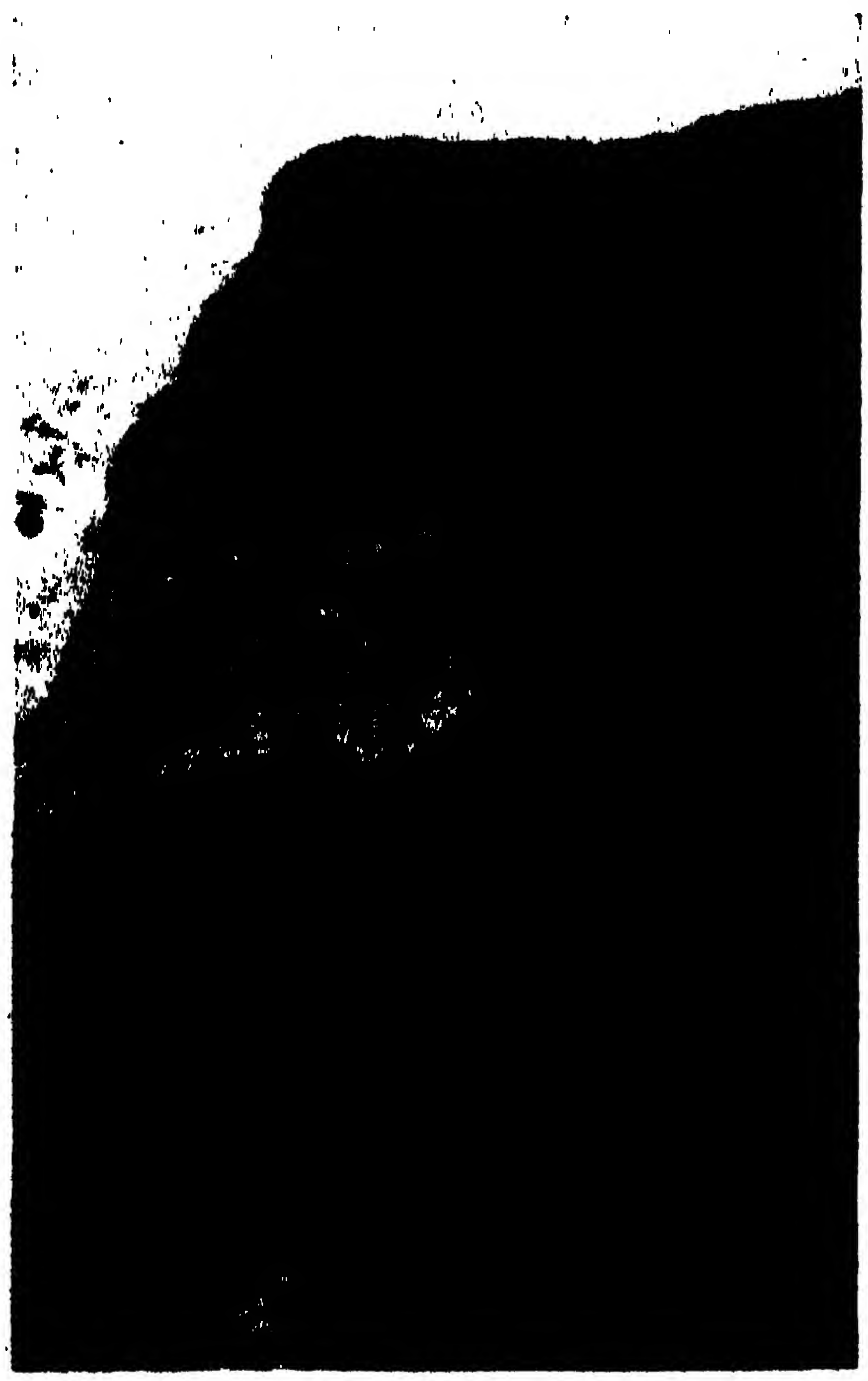


FIG. 5. AVERAGE WIND VELOCITIES AT 3 P.M., WHICH IS THE TIME WHEN WINDS GENERALLY ARE HIGHEST. (AFTER ATLAS OF AMERICAN AGRICULTURE.)

[7] *Op. cit.*, p. 163.

[8] *Loc. cit.*



Gila Pueblo, Globe, Arizona

FIG. 6. PEDOCALIC SOIL

EXPOSED IN A BANK NEAR ABILENE, TEXAS. LIME CARBONATE HAS ACCUMULATED IN THE SUBSOIL, FORMING THE WHITE DEPOSIT KNOWN AS CALICHE.

V

The recent dust storms were the natural results of deficient rainfall, depleted subsoil moisture and greatly reduced vegetation in a region of loose, dry, soil and strong, turbulent winds. These factors prevailed in both the northern and southern portions of the High Plains. According to the Weather Bureau,[9] there was an increasing deficiency of moisture at St. Paul during the 22 years preceding 1934. From 1926 to 1933, the average annual rainfall was three inches less than the normal amount.

No such prolonged period of moisture deficiency seems to have affected the southern High Plains, although in 1933 the annual precipitation at Dalhart, Texas, was 10.14 inches and in 1934 it sank to only 9.78 inches—slightly more than half the average over a period of 27 years.[10] In the first 10 months of 1936, rainfall in North Dakota was 50 per cent. of normal; in South Dakota, 52 per cent.; in Montana, 75 per cent.; in Nebraska, 68 per cent.; in Kansas, 69 per cent.; and in Oklahoma, 70 per cent.[11] These deficiencies reduced crop yields and also brought grave harm to the protective vegetation on soils.

In addition to their serious damage to the soils, dust storms have brought tragedy and loss to human beings. They have destroyed lives, created discomfort and illness among thousands, killed livestock, made highways impassable, ruined motors, damaged the contents of stores, factories and homes, buried orchards, fields and gardens, and disrupted commercial production. They also have brought darkness in mid-day, and have spread mud-rains far and wide over the country.

During March and April, 1935, there were 47 days on which visibility at Amarillo, Texas, was limited to 6 miles or less; during the majority of storms it was one mile or less and during six storms it was less than 500 feet (Joel). Fifteen storms lasted longer than 24 hours, and four lasted 55 hours or more. After the dust reached the higher levels of the atmosphere it was carried hundreds of miles. In eastern Illinois there were days when the atmosphere held so much dust that the sky was murky and the sun shone red. Some of this dust was carried even to the Atlantic Coast.

If such dust storms were to become the rule, they might have even other serious consequences. The interception of heat rays from the sun would retard normal heating of the earth's surface, reduce average temperatures, diminish plant

[9] C. E. Kellogg, U. S. Dept. Agriculture, *Misc. Pub.*, 221: 2, 1935.

[10] Joel, *op. cit.*, p. 62.

[11] G. K. Rule, Soil Conservation Service, U. S. Dept. Agriculture, Circular 430: 1, 1937.

growth and adversely affect weather conditions other than those of temperature.

Contrary to the common impression, dust storms of the 1930's are not the only destructive ones that have swept the Great Plains. The subnormal moisture conditions which set the stage for these storms occur in cycles. Climate has its pulsations on both small and large scales and over various periods of time. Any plan devised to offset wind erosion or soil drifting must consider cyclic changes. It must also take into account the fact that soil tillage over a period of years reduces the humus content, unless special treatment is given, while lowered humus content, in turn, reduces the moisture-retaining capacities of soils. In consequence of these changes, recent dust storms were more destructive and more wide-spread than they otherwise would have been. The dust storms of future dry cycles will grow even more destructive if reduction of the soil's humus continues.

Soils may vary greatly within relatively small areas and hence differ in their susceptibility to wind movement. Removal of the top soil may expose a relatively compact heavy subsoil which impedes erosion, but such material is likely to be less tillable and less productive than the soil that has been carried off. In dry regions, as we have seen, this subsoil commonly is caliche (Fig. 6), which may be as hard as some ancient limestone. Such material obviously is unsuited to the production of crops.

Uniformly fine, sandy soil favors wind transportation, especially after plowing. On the other hand, soils which consist of large aggregates of clay and silt, bound by clay-minerals such as beidellite, do not blow readily. Small aggregates of "fluffy" character, whose particles are as small as sand grains, but lighter, will drift very readily.

Topographic position is also a factor in wind erosion. Soils on windward slopes and brows of hills in rolling country are particularly vulnerable to attack, while deposition is favored on the leeward side. This combination of erosion and sedimentaion must eventually result in "spotted" agricultural conditions, reduced production and lowered land values.

VI

The geologist looks upon the problem of wind erosion in the Great Plains from a viewpoint which differs from that of the non-geologist. Every earth historian knows that dust storms of the Glacial Period were greater and more protracted than those of the 1930's. He also knows that certain definite conditions brought those storms to a close, introducing a long period of soil stability.

Fig. 3 shows the wide-spread distribution of the ancient, wind-blown dust deposits which are known by their Alsatian name of loess. In Nebraska alone there are 42,000 square miles of loess whose thickness in many places reaches scores of feet. This deposit extends into northern Kansas. Loess covers the western, southern and eastern portions of Iowa, and, at Council Bluffs, forms high hills on the east side of the Missouri River. A thin loess sheet covers the northern part of Missouri, becoming thick along the Missouri River. In Illinois, loess covers much more than half the State; it extends into southwestern Wisconsin, southeastern Minnesota, southern Indiana and the northern fringe of Kentucky. Other loess deposits follow southward along the Mississippi River to its modern delta.

This great sheet of wind-blown dust came from many sources. Some authors say that the loess of Nebraska and Kansas came from the Sand Hills region and from large river valleys, such as the Platte. Some of this dust floated onward to Iowa, Missouri and other states to the eastward, just as dust floated in the recent storms, but most of the loess in western Iowa seems to have been blown

A. G. Lugn, Nebraska Geological Survey

FIG. 7. LOESS NEAR GREELEY, NEBRASKA

AFTER THE LOWER LOESS (DARK FROM WEATHERING) WAS FORMED THERE WAS AN EPOCH OF MOISTURE AND WEATHERING. THEN DUST STORMS WERE RESUMED, DEPOSITING THE UPPER, LIGHT-COLORED LOESS.

from the Missouri flood-plains. That in eastern and central Iowa came from the Iowan drift-sheet and from valleys which received outwash from the Iowan glacier. The thick loess of western Illinois probably was blown from glacial outwash along the Mississippi, while that near the Illinois, Wabash, Ohio and other large streams apparently came from their wide, once-barren, aggraded valleys.

Loess deposits which lie at the surface are known to have older loesses beneath them. Fig. 7 shows an old loess deposit on which weathered soil developed before it was covered by a new bed of dust. Many similar exposures are known. They record several distinct epochs of dust storms and soil-drifting—all during the Glacial Ages, when man was not tilling the plains and prairies of North America.

What is the story of these ancient dust epochs? What caused their succession, their renewal and their final termination?

In answering these questions we must stress the fact that *the dust epochs have terminated.* No appreciable amount of material has been added to the loess of the Mississippi Valley since the last glacial epoch. The evidence of this is definite:

First, the last glacial drift, which extends southward to Des Moines, Iowa, as is shown in Fig. 3, is free from any cover of loess. The soils of the large area which it covers have been made from the drift itself. Loess deposits which surround the Des Moines lobe pass under the drift, as observers may see clearly in railroad and highway cuts.

Second, the loess of Iowa, Illinois, Missouri, and immediately adjacent areas has distinct and normal profiles of weathering. The normal thickness of topsoil is present, and below it are the usual traces of weathering, similar to the soils made from the last glacial drift. The development of such "soil profiles" in both loess and drift required thousands of years of stable conditions. The loess of these states, therefore, can not be of Recent Age.

The Glacial Period embraced both glacial ages and inter-glacial ages. To which does the loess belong?

The answer to this question lies in certain relationships which the loess of large areas bears to the main lines of glacial drainage and to certain drift deposits, as well as in fossil shells which are found in loess accumulations. Along those very broad valleys which received relatively fine outwash deposits of distinctive colors, the bordering loess has those same colors. It is also thickest and most sandy along the valleys, but becomes progressively thin and fine-textured away from them. These relationships leave no doubt that the loess was deposited while the valleys were being aggraded with fine valley-train material and while absence of vegetation from valley flats gave the winds a chance to pick up sand and dust. The lodgment of the sand and dust on the valley slopes, crests and uplands was due, at least in part, to vegetation of the open forest type, as is shown by the shells of pulmonate woodland snails which are found in the loess. This relationship of loess deposition to what once were barren valley trains—barren because they were being built—is constant and shows that the dust drifted and settled while the ice sheets were melting. This conclusion holds good for the Mississippi Valley from Minnesota to the delta, for the Ohio River along its lower course, for the Illinois River from the Big Bend to its mouth, for the Missouri River as far upstream as Sioux City and for such tributaries of the Mississippi as the Des Moines, Cedar and Iowa rivers. In most of these cases, loess on the eastern sides of valleys is much thicker than that on

FIG. 8. LOESS INTERBEDDED WITH GLACIAL DRIFT

IN THE BANKS OF FARM CREEK, NEAR PEORIA, ILLINOIS. THE ILLINOIAN DRIFT (A) IS OVERLAIN BY TWO DEPOSITS OF LOESS (B AND C), ABOVE WHICH ARE DRIFT (D) AND LOESS (E) OF THE WISCONSIN GLACIAL AGE. LOESS C WAS DEPOSITED JUST BEFORE THE WISCONSIN GLACIER ARRIVED; LOESS E, IMMEDIATELY AFTER ITS RETREAT.

western sides, indicating the dominating influence of the westerly winds, which still prevail in the Central Lowlands.

So much for the valley relationships of the loess, which show its sources and time of deposition in the Central States. We now may consider the meaning of its relationships to certain drift sheets which formed as glacial ice melted.

Calvin and others long ago discovered that the Iowan drift sheet, of northeastern Iowa, had definite and apparently genetic links with the loess deposits about its borders. There are stretches, scores of miles in length, where the loess begins abruptly, thins marginally in morainal fashion, is sandy, bears dune-like hillocks and grades progressively with distance into a fine-grained, thin sheet. In some spots, a thin mantle of loess covers the drift itself; where the basal part of this loess is unweathered, the underlying drift is unweathered also. In other words, there is definite evidence that such loess was deposited promptly after the Iowan ice melted.

The famous exposure along Farm Creek, near Peoria, Illinois (Fig. 8), shows that dust was drifting and settling during both the advance and retreat of the early Wisconsin ice sheet. There the first Wisconsin drift was spread upon unweathered loess which still contains evergreen wood and moss, the latter being specially common at the top of the dust deposit. The drift, in its turn was covered by loess before it had time to weather perceptibly. Beyond the limits of the drift, the upper and lower loesses merge—also without trace of an interval of weathering.

The point of all this—and there is more evidence were it needed—is that the ancient wind-blown dust of the Mississippi Valley states, generally known as the Peorian loess, is not interglacial but is glacial. It was picked up and deposited by strong winds which swept across barren stretches of fine, newly-laid outwash or silty drift. Pockets of dust are formed by the same means to-day near remains of steadily melting glaciers in Alaska and the northern Rockies.

Let us now consider the loess deposits formed on the Great Plains. Most glaciologists agree that the climate of the Plains was moist during glacial epochs, but that it was dry during interglacial epochs, just as it is now. Some authors therefore infer that the Nebraska loess was laid down in an interglacial epoch when ice was far away. This seems to be an error, for the latest Wisconsin drift area contains virtually no loess, and the yellow dust beds of Nebraska and states to the eastward are identical in age. We already have seen that the loess of Illinois was deposited during times of ice advance, as well as while nearby glaciers were melting.

Lugn[12] has shown that the Nebraska loess came from both the Platte Valley and the Sand Hills. The part which came from the Platte was derived from a wide valley train whose source was mountain glaciers of the Rockies; that train was not covered with vegetation because it was being built. Valley slopes, divides and uplands did bear plants, which caught and held drifting grains of dust. As for dust from the Sand Hills: it apparently was sorted out and removed during the interval of transition from the moist, glacial to the dry postglacial climate. This change apparently was so rapid that there was only a brief period between the death of protective plants which had grown during moist times and the arrival of drought-resistant species. During that break the Sand Hills were unprotected from the high winds that swept across them and continued eastward beyond the Missouri. When drought-resistant plants became established, wind erosion again became trifling. Since that happened, soils have formed extensively, proving

[12] *Op. cit.*

that relatively stable conditions prevailed until the white man arrived.

VII

The dust storms which we have just considered ended long before men brought farming and grazing into the Great Plains. Nevertheless, they allow us to draw four conclusions of value to them who now are attempting to mend the damage wrought by unwise use of the land:

1. Dust storms will occur in even a moist climate if broad areas of fine rock material, without vegetative cover, are exposed to the wind. This is true whether the exposure is due to natural causes or to the turning of the sod by man's plow. In the Middle West to-day, winds are removing soil from plowed fields, though more slowly than they take it from the dry Great Plains and the semiarid High Plains.

2. The general prevalence of a definite soil profile over the Great Plains, and even the High Plains, shows that their climate is not too dry for a general vegetative cover to develop if it is permitted to do so. Man's activities, carried on without a knowledge of or regard for the economy of nature, are responsible for dust storms of modern times.

3. In the High Plains, and under some conditions of soil and topography on the relatively low plains, the opposing factors are so nearly critically balanced that man must act with intelligence and skill if he is not to lose his greatest resource. If he follows proper methods, there is hope for the "dust bowl" of the High Plains as well as for the fertile Central Lowlands.

4. The short climatic cycles probably produced local but not wide-spread wind erosion under virgin conditions. But man's work is a new and powerful geologic factor which must be used with caution, especially during the drier parts of these minor climatic cycles, lest it result in soil-drifting and deposition on a nationally destructive scale.

A DRUG OR POISON?

By Dr. DAVID I. MACHT
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To the average layman the terms *drug* and *poison* denote two substances as absolutely separate and diametrically opposite as the poles. Many pharmacists and even physicians regard drugs and poisons as distinct and separate entities belonging to two different classes of chemicals. If one were to take a heap of drugs and attempt to classify them in containers to which the labels *Drug* and *Poison*! had been respectively affixed, he would experience the greatest difficulty in deciding to which group any particular substance belonged. As a matter of fact, modern pharmacology and experimental medicine have proved that there is no sharp line of demarcation between drugs and poisons. Indeed, every drug that is worth anything as a medicinal agent is also a poison; and, *vice versa,* almost every poison, under certain conditions, exerts a useful medicinal action and may therefore be regarded as a therapeutic agent. Here, as in almost every phase of human activity, the principle of relativity prevails.

The close relationship of medicament and poison is actually implied by our word "drug," which in its absolute sense denotes not only a remedy but also "dope." The Greek word *pharmakon* was similarly applied to both drug and poison. The ancient Hebrews employed the word *sam* for drug and also for poison and differentiated between the two by prefixing qualifying terms implying life or death. It was the *sam,* or "elixir," of life or the *sam,* or "elixir," of death. The Russian *yad* has the same double meaning, and in other languages the word for drug has a similar dual significance.

The most obvious criterion between a medicinal or poisonous effect of any substance is its dosage. That is the idea conveyed by the German word *Gift,* derived from the root "to give." The dosage is truly a most important factor denoting the difference between useful and harmful effects of chemicals. And so it came to pass that the ancients coined the Latin adage, *Dosis sola venenum facit,* "The dose alone determines the poison." The dose of a drug, however, is only one of many factors which qualify its physiological action on man and animals. In fact, so many conditions are now recognized as influencing the action of chemicals that no distinction is made between the sciences of pharmacology and toxicology. From the standpoint of modern science, the two subjects deal with complementary aspects of the same theme and are now generally comprehended under the one term, *pharmacology.*

Whether a given substance will act as a medicine or poisonous agent will depend on four sets of factors, elsewhere described by the writer as the "four dimensions" of pharmacodynamics. The first group depends directly on the subject—man or animal—to which a specific drug or chemical is given. Thus, for instance, belladonna is better tolerated by children than by adults, even though the dosage in relation to the respective weights is much greater for the young. On the other hand, various opiates and narcotics, even when administered in relatively small doses, are much more dangerous for the young than for the old. Again, various species of animals often exhibit an enormous difference in their reaction to a given chemical, and so the therapeutic dose computed from experiments on one or two species of lower animals—for instance, the guinea pig or rabbit—does not *per se* afford an absolutely reliable index to the correct dosage for a

human being. Such data obtained from lower animals usually serve only as *leads* which guide the careful pharmacologist in computing the smallest dosage to be administered to a human being and gradually increasing it to its most effective magnitude after cautious clinical experimentation.

The second group of factors depends on the drug itself. Of course, certain chemicals are intrinsically more active physiologically than others but, aside from that, here are to be considered the dosage of the drug or chemical, the concentration and other properties dependent directly on the drug itself. For instance, arsenic in small doses is a helpful blood tonic; in large doses, it is a horrible poison. Minute doses of such a salt as sodium cyanide, universally regarded as a poison, have actually been employed by Loevenhart and others as a respiratory stimulant because it has been shown that the cyanide ion, in very small quantities, is a stimulant to the respiratory center, while slightly larger doses thereof produce paralysis of the respiration and death. Every one mentally labels the cyanides, *Poison*! and justly so, yet it has been shown that even these compounds in suitable doses exert a useful therapeutic action.

To the third group of factors belong external conditions which may profoundly modify the action of drugs and chemicals and spell the difference between a therapeutic and a toxic effect. In this connection, the method of administration is often of great importance. Most drugs are administered by mouth; others, however, may be injected subcutaneously, intramuscularly and intravenously. Either of the two methods of administration may be chosen in some cases merely as a matter of convenience or at most in order to secure a quicker or slower action of the drug. When administered by mouth, however, many substances exert a physiological action entirely different from that which they evidence when given by injection. In other cases, injection of a drug may produce an entirely different pharmacological effect from that obtained by oral administration of the same substance. Thus, magnesium sulfate, which is ordinarily administered by mouth, is a harmless and very effective saline purgative. If a solution of magnesium sulfate be injected subcutaneously or intravenously, however, a paralysis of the central nervous system is produced because the magnesium ion, which is not readily absorbed from the gastro-intestinal tract, is absorbed after injection of the drug and poisons the nerve tissues. When given by mouth, epinephrine produces no physiological effect in a patient because it is destroyed by the digestive juices; when the same drug is administered by subcutaneous or intravenous injection, however, it rapidly effects a powerful stimulation of the heart, constriction of the blood vessels and dilatation of the bronchioles. Many other such external circumstances or conditions exert a profound influence on the physiological action of drugs and chemicals. Thus, for instance, it has been found that paramecia, placed in solutions of the fluorescein dye, eosin, or tetra-brom fluorescein, die soon after exposure to sunlight; while paramecia placed in similar solution but kept in the dark live on indefinitely. In such a case the ultra-violet rays potentiate the toxic action of the dye.

Meteorological conditions may also affect the action of certain drugs. The writer has recently shown that barometric pressure profoundly affects the potency of our best known cardiac stimulant, tincture of digitalis. For a long period, he made systematic records of barometric pressure and weather conditions in his laboratory and correlated these data with the results of his frequent assay of digitalis tincture. When a sudden and violent storm broke over Baltimore and the barometric pressure fell abruptly from 2 to 3 cm, it was found that the potency of digitalis, as tested by the cat method, was

increased. Similar findings pointing to a definite relationship between the barometric pressure and the toxicity of digitalis preparations were obtained by the writer and his colleagues in the assay of samples from a common stock at sea level and in the Blue Ridge and Rocky Mountains and in the Tyrolean Alps.

The importance of the fourth dimension of pharmacodynamics, or the time factor, which often plays a leading role in the action of drugs, has hitherto been little appreciated. One or two concrete illustrations will impress the reader with its consequence. The salts of quinine, administered by intravenous injection, are often a life-saving drug to patients affected with pernicious malaria. Ordinarily, a dilute solution of quinine hydrochloride is very, very slowly injected into a vein. Such a slow infusion of the alkaloid permits its distribution through the circulation to the various organs and tissues of the body without undue depression of the heart. If the solution of quinine be injected rapidly into the patients' vein, however, its concentration in the blood stream becomes so great that it depresses the myocardium, stops the heart-beat and induces death. In this case, the difference between the life-saving and the life-destroying procedures is marked by the difference in speed of administration of the drug. Even such an innocuous salt as potassium chloride, usually not regarded as a poison, may act in the same way when intravenously injected. Thus a 5 per cent. solution of potassium chloride, very slowly injected into a vein of a rabbit, cat or dog, will scarcely produce an untoward result because this particular salt is so rapidly absorbed from the blood stream and excreted from the kidneys, producing diuresis, that the characteristic depressant action of potassium for heart muscle is too slight to be noticed. When the same solution of potassium chloride is rapidly introduced into the circulation of the same species of animal, however, the concentration of potassium ions in the blood stream is sufficient to depress the heart muscle, arrest the heart-beat and hasten a lethal outcome.

The time factor plays an important role not only in connection with the speed or rapidity of administration of drugs but also in respect to the *time when* such chemicals are to be given, the duration of repeated doses, their relation to time of feeding and in connection with their acute and chronic effects. The time factor also plays a most significant role in connection with the phenomenon of *synergism*, or a greater potentiation of toxicity of two or more medicaments given at the same time than can be explained by the simple summation of their individual effects, because pharmacological research has revealed that two or more drugs, administered simultaneously or in rapid succession, may profoundly affect the action of each other.

The foregoing remarks indicate that there is no definite demarcation between the therapeutic and poisonous physiological action of any given chemical. The writer goes further, however, and states that the principle of relativity plays a role even when the toxic effects not of medicaments but of so-called poisons are compared. Most laymen, and even many pharmacists and physicians, designate various poisons as mild, violent, virulent, etc., without stating exactly what standard of comparison they use in classifying such substances. A chemical may be termed a violent poison because of its rapidity of action, yet on closer examination it may be found that with regard to lethal dosage it is much weaker than some other poisons. Another poisonous chemical may be very potent indeed with respect to the minute quantity required to kill an animal and yet not be regarded as a violent poison because its action is exerted over a comparatively long period. Failure to compare chemicals by some definite standard when describing and classifying their toxic effects has led to

much confusion and misunderstanding concerning the action not only of poisons but also of medicinal substances. The necessity for comparing chemicals by some definite standard is a subject worthy of considerable discussion. Its importance may be better illustrated perhaps by a brief description of portions of two researches recently conducted by the writer. One of these was a pharmacological study of cobra venom, the other an historical investigation concerning the drugs and poisons mentioned in Shakespeare's Romeo and Juliet.

The bites of venomous reptiles, often fatal, have always been regarded as very poisonous. From time immemorial the venom of poisonous snakes has been called a poison *par excellence.* Recently medical investigators have discovered that, far from being poisonous, minute doses of certain snake venoms actually constitute valuable medicinal agents. Some of these venoms have therefore been introduced into practical therapeutics. Thus, for instance, it has been found that small doses of crotalin, or the venom of the rattlesnake, have a sedative effect on patients suffering with cerebral convulsions. Rattlesnake venom has accordingly been employed therapeutically with considerable success in the treatment of epileptic seizures. Other investigators noted that the venom of the moccasin promoted coagulation of blood, and this venom in suitable doses has been employed with a measure of success in the treatment of certain forms of hemorrhage. Moreover, it has been claimed that the venom of the viper *Russellii* is useful in the treatment of hemophilia. Most interesting of all, however, are the recent studies published in France and America on the remarkable analgesic or pain-relieving property of graduated minute doses of the attenuated venom of the most deadly of all reptiles, the cobra (Naia). Much scientific research has been done with this venom by investigators at the Pasteur Institute, France, and a number of papers have been published by the writer in this country. These experimental laboratory studies have been followed by clinical observations which leave no doubt regarding the usefulness of suitable doses of carefully assayed cobra venom in treating the intractable pains accompanying inoperable malignant tumors and similar conditions. So the venom of the cobra and that of other snakes, for centuries regarded only as a poison, has proven in the light of modern scientific research to be a useful medicinal agent.

The student of classical literature will find that "Romeo and Juliet" probably contains more references to drugs and poisons than any other of Shakespeare's plays. The writer has made a rather extensive study of this particular play. In a lecture entitled, "A Pharmacological Appreciation of Romeo and Juliet," he has pointed out its wealth of historical material with regard to materia medica and Shakespeare's remarkable acumen in formulating certain pharmacological hypotheses or laws in striking accord with the findings of modern pharmacology. One of the best-known passages in Romeo and Juliet is that in which Romeo demands of the impoverished apothecary "such soon-speeding gear" as will quickly and most certainly dispatch him. Here the question should be raised, What was the poison which Romeo obtained and how quickly could such a drug effect his death? Pharmacological and historical research leaves little doubt as to the probable identity of the poison mentioned in that scene. According to some, it was the hemlock, *Conium maculatum,* but according to others, whose views are more in agreement with modern toxicological findings, it was monkshood or aconite. This poison was probably the most rapidly acting and potent poison known to the ancients. Indeed, its rapidity of action is specifically mentioned in "King Henry IV."

Learn this, Thomas,
And thou shalt prove a shelter to thy friends,
A hoop of gold to bind thy brothers in,
That the united vessel of their blood,
Mingled with venom of suggestion,—
As, force per force, the age will pour it in,—
Shall never leak, though it do work as strong
As *aconitum or rash gunpowder.* ·

Could crude aconite, taken by mouth, produce so rapid a death as that described in Shakespeare's play? The answer must be in the negative. Death within a few minutes could only be induced by injection of the active principle of aconite, or aconitum, which, of course, was not available at the time the play was written. Shakespeare therefore indulges in poetic license when he allows Romeo to die immediately after swallowing the drug. Poynter's story of Romeo's death is more in accord with scientific facts. Even more in agreement with the actual pharmacological findings is the account given in Gounod's opera, in which Romeo lives long enough to sing an aria to Juliet.

It is essential that the researcher making a rational comparison of the potency of two poisons reveal the exact conditions under which they are examined or tested. Obviously, this can be done only if one set of variables is compared, while all others are kept constant or carefully controlled. Here again, the element of relativity prevails and as in case of drugs in general four factors are to be considered: the first is the animal poisoned; the second, the physical and chemical properties of the poison itself; the third, the various external factors modifying its action; and the fourth, the element of time. In practical experimentation with different poisons it is especially necessary to control the species of animal employed, the dosage and concentration of the poison if given in solution, the portal of entry and the speed of administration. To illustrate the differences in potency of various poisons studied by such a scientific method, the writer has carried out a series of experiments with a number of well-known powerful chemicals according to the following procedure. Solutions of the poisons, usually, 1:10,000 (but in some cases more concentrated, *i.e.*, from 1:1,000 to 1:5,000), were slowly injected from a burette into the femoral vein of a cat kept under ether anesthesia. Each solution was injected at the rate of 1 cc every half minute. Blood pressure and respiratory movements were recorded on a slowly moving kymograph, while injections were continued until death of the animal. The lethal dose of each poison per kilogram weight of cat was then calculated. Comparison of the different poisons was made by the same procedure in each case. The poisons examined in this way were atropine sulfate, cocaine hydrochloride, aconitine hydrochloride, nicotine alkaloid, conium hydrochloride, potassium cyanide, sodium arsenate (1:1,000), cobra venom, rattlesnake venom, ouabain, ricin and abrin. The findings obtained are shown in the subjoined table. The results obtained with ricin and abrin are not recorded in the table because it was practically impossible to kill the animals with these substances by the procedure described above. While in point of lethal dosage they were poisons of extreme physiological activity, ricin and abrin required a long period of time to produce death.

The castor oil bean, *Ricina communis,* contains within its shell a substance called ricin, which does not ordinarily pass into the oil. While ricin is an extremely poisonous substance, the symptoms it induces do not usually set in until several days afterward, an incubation period being required for the complete action of the drug. Ricin is a protein-like body often termed toxalbumin, and its activity has been cited as greater than that of any other poison known. As little as 0.0005 mg per kg is fatal to a rabbit; that is, one part of ricin is fatal to two million parts of rabbit. Abrin, a drug obtained from the jequirity seed,

closely resembles ricin in its action. It is also very poisonous with respect to the infinitesimal dosage required to produce death, but abrin, like ricin, acts very slowly. Curiously enough, this particular toxin was once therapeutically employed for clearing the corneal opacities. Here is another instance of a dreadful, subtle poison, infinitesimal in its dosage, which is employed under certain conditions as a medicament.

In its action the highly potent hydrocyanic or prussic acid exhibits the converse of ricin and abrin. This chemical constitutes a classical example of a "violent" poison, denoting by that a substance very rapid in its action without referring to the quantity required to produce death. Death from hydrocyanic acid usually occurs in a few minutes. Its lethal dosage, however, generally given in text-books as 1 gr, or 65 mg, does not compare with that of a number of alkaloids and other poisons listed in Table 1. The fatal dose of hydrocyanic acid is from 3 to 5 grains or from 0.2 to 0.3 gram.

TABLE 1

LETHAL DOSE PER KILO WEIGHT OF CAT

Atropine sulfate	36.0 mg
Strychnine sulfate	2.50 "
Cocaine hydrochloride	10.0 "
Coniine hydrochloride	3.0 "
Nicotine alkaloid	1.3 "
Aconitine hydrochloride	0.28 "
Potassium cyanide	2.2 "
Sodium arsenate	187.50 "
Cobra venom	1.04 to 2.60 "
Crotalus ruber	20.0 "
Ouabain	0.10 "

Examination of the comparative table of lethal dosages obtained by the method described above reveals that by far the most important powerful poison in the list is aconitine hydrochloride, of which only 0.28 mg per kilo weight of cat was required for the lethal dose. Next in potency was the alkaloid nicotine. The lethal dose of this alkaloid per kilo weight of cat was found to be 1.3 mg. The writer has also shown elsewhere that, unlike the salts of other alkaloids, the salts of nicotine are somewhat less poisonous than the alkaloid itself. Furthermore, it is well to note that both aconitine hydrochloride and nicotine alkaloid are such penetrating poisons that a small quantity applied to the mucous membranes of the mouth or eye is rapidly absorbed, producing death. Of *Conium maculatum,* or hemlock, 3.0 mg per kilo weight of cat were required for the lethal dose, while that of strychnine sulfate was 2.5 mg. The other alkaloids of the series, namely, atropine and cocaine, when tested by the method mentioned above, proved to be much weaker. Ten milligrams of cocaine hydrochloride per kilo weight of cat were required to kill, while the minimal lethal dose of atropine sulfate was 36.0 mg. Sodium arsenate is a good example of a deadly poison not very rapid in its action. Animals poisoned with arsenic usually survive for several days. Even when the drug is injected into a vein by the method described, 187.5 mg per kilo weight of cat are required to kill. Of timely interest are the figures obtained with cobra venom, the lethal dosage in this case varying from 1.04 to 2.6 mg per kilo weight of cat. The variation in the lethal dosage was due to the action of different specimens of cobra venom employed. Cobra venom, like all other animal poisons, is not very stable and is affected by temperature, light and other physical agents. Rattlesnake venom is even more susceptible to heat than cobra venom. The venom of *Crotalus ruber* is twenty times weaker than cobra venom. From the standpoint of medicine and pharmacy, probably the most interesting figure in the foregoing table is that obtained with the glucoside ouabain. The physician and pharmacist do not regard ouabain as a poison because it is an invaluable heart tonic in extreme cases of heart failure, yet the lethal dose of this drug per kilo weight of cat is 0.1 mg, less

than half that of aconitine hydrochloride, the most potent poison listed in the table. Here is an excellent illustration of the rôle played by the element of relativity in our psychological conceptions of drugs and poisons.

The figures given above show the relative potency of different poisons when injected intravenously. An entirely different story was told when the same substances were administered to animals by stomach tube, a story which emphasizes the importance of accurately stating the exact conditions under which drugs or poisons are compared. Fluid extract of aconite, given to cats in doses of 3 cc per kilo weight, produced death only after twelve hours. The same dose, 3 cc per kilo weight, of fluid extract of *Conium maculatum*, or hemlock, produced only a mild depression from which the animal recovered the following day. Fluid extract of hyoscyamus, even in doses of 10 cc per kilo weight by stomach, produced only mild depression. The same results were obtained with 10 cc per kilo weight of fluid extract of belladonna. On the other hand, 2 cc of dilute hydrocyanic acid, introduced into the stomach of a cat weighing 2.5 kilo, produced death in less than three minutes. Inasmuch as hydrocyanic acid was not known to the ancients or until the development of modern chemistry, the tales of rapid poisoning with all kinds of dreadful concoctions to be found in classical literature, including Shakespeare, are to be read with reservation and with due concession to poetic license.

What lessons may be drawn from this brief discussion concerning the potency of drugs and poisons? It is established that there is no absolute or definite line of demarcation between the poisonous and medicinal action of any drug. Any drug is a potential poison and, conversely, almost every poison has a practical value and may be employed, under certain conditions, as a medicinal agent. The difference between the beneficent and harmful physiological effects of any given substance is determined by the four dimensions of pharmacodynamics or factors depending (1) on the animal or patient, (2) the drug itself, (3) various external modifying conditions and (4) the element of time. Again, it has been emphasized that the potency or virulence of a poison can not be adequately described unless the exact conditions under which it has been studied are definitely stated. A substance may be a very violent poison with respect to its dosage or the minute quantity required to kill and yet a comparatively mild one with respect to its speed of action. *Vice versa,* other poisons, which may be described as very powerful with regard to their rapidity of action, are found on closer study to be comparatively weak with regard to their lethal dosage. Moreover, our conceptions of drugs and poisons are often distorted by our psychological outlook and colored by our sentiments, especially with regard to practical and popular uses of medicinal substances. This is true not only of the layman but also of the pharmacist and physician. Thus cobra venom is universally considered a dreadful, rapidly acting, death-dealing poison, yet in suitable doses of properly assayed solution, it is a valuable therapeutic agent for the relief of pain. On the other hand, neither pharmacist nor physician thinks of ouabain, or crystalline strophanthin, as a poison because he regards this drug as a heart tonic, yet its lethal dose is actually smaller than that of aconitine, the most poisonous alkaloid known. Finally such a comparative study as the foregoing serves to emphasize the immense value of a training in scientific methods of thinking.

"To be or not to be—*that* is the question." Is the compound employed to act as a drug or is it perhaps to become a dangerous poison for lack of consideration of all the factors that play a role in its administration? The riddle has been solved at the cost of infinite labor and unending research.

COLOR IN FOOD, COSMETICS AND DRUGS

By Dr. HERMAN GOODMAN
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To introduce the subject of color additions in food, cosmetics and drugs in a few minutes I can but give highlights of the past, comments on the present and guesses for the future.

Color always appealed to man, and throughout history, color attraction led to experiment in berries, fruits, vegetables. There is a veritable natural spectrum in a vegetable platter. Your choice of strawberry probably depends upon the color idiosyncrasies of your inheritance in visible purple, and the volume of vitamin A you consume. No doubt the crafty Phoenicians sought to adulterate foods in their search for color, as the eastern peoples were long interested in the art. The Egyptians used pigments and we recall the range with which Cleopatra intrigued Anthony: green beneath her eyes, black to the eyelids, lashes and eyebrows, henna for finger and toe nails and for the palms. The ancient Hebrews were not far behind in their use of color for decoration of the person. Spices for food and incense were likewise tinted. The Greeks and later their Roman conquerors fell heir to a color-tinting secrecy which in turn reached the Byzantians and the other eastern people. The Koran of Mohammed refers to the material used for darkening the eyes under a name which persists to this day—Kohl. The art of tattoo and war paint may rightfully belong to this subject.

Color was the right of royalty, as witness the name "royal purple." The economic interpretation of history would impress us with the assumption that the search for the northwest passage or shorter route to the Indies was one for spices and for color. The pirates along the land route exacted too high tribute, and so Columbus discovered America, as the western hemisphere's continents came to be known.

Needless to say, all color was of natural sources as vegetable, animal or mineral. The production of such natural colors kept entire sections of people occupied and happy. But there must be change, and possible progress. So we come to the year 1838—one hundred gone—for on March 2 of that year, William Henry Perkin was born. While still a youth of 15, he hit upon the discovery of manufacture of mauve—the first artificial color—from coal tar. He was on vacation in his father's kitchen experimenting in fields which his elders dared not tread. Enough for us that what may have been an ignoble trial led to remarkable results. They upset the entire industry of natural color sources, and created a new, wider, bigger and possibly better world. Strange, too, that the first color drawn from the tar barrel should have been purple-royal purple of the ancient Phoenicians. Strange, too, that the boy's Easter vacation kitchen chemical trial should make it possible to bring purple to the lowliest of the subjects of royalty which once alone wore it.

Because Perkin did not throw away the ugly mess he had made in his unsuccessful efforts to create artificial quinine, the tar barrel has been forced to yield a part of its color horde. One can not name all the colors derived from coal tar. The methods initiated by the youth were improved upon, but to Perkin remains the glory.

We can not go into the development of Perkin's fundamental idea, but I can not refrain from introducing another boy into this story. Paul Ehrlich was two

years old in 1856 when Perkin uncovered mauve. He was a lad in his teens when he decided that chemistry was his life work. He displeased his teachers by interpreting all his work in terms of chemistry and chemical symbols, which the elders did not understand. Paul Ehrlich took the dye-stuff gifts of Perkin and founded a new attack on disease. He was the first to study the constituents of the blood, and distinguished the members of the white blood cell series. He discovered the acid-fast nature of the tubercle bacillus recently discovered by Koch. Incidentally, he acquired tuberculosis during his experiments. Vital staining was stressed by Ehrlich. He named the gonococcus. He advanced the side chain theory so useful to future experimentation.

We digress a moment to show the growth of the boy Paul Ehrlich. He digressed from experimental work with color. He evaluated and standardized diphtheria antitoxin and studied the oxygen requirements of the living organism. The side chain studies culminated in the discovery of the serological reaction for syphilis. Wassermann publically proclaimed that had it not been for Ehrlich's work on the side chain theory of immunity, he never would have hit upon the reaction. We mention sadly that experimental work on therapy of cancer failed despite the fields of thousands of experimental animals and painstaking endeavors.

We return to the colors or dyes which Ehrlich brought to relieve human suffering. About 1906, Ehrlich began his experimentation with dyes beginning with atoxyl. He passed through additions and modifications. After 606 experiments, the dye we know in the United States as arsphenamin—discovered as salvarsan—and chemically, dioxydiaminodiarsenobenzol—was made and used successfully in animals. The dream of *therapia sterilisans magna* remained a dream, but the dye formed by Ehrlich from the self-same tar barrel as gave Perkin his purple is no dream. Other recent dyes found useful in treatment of disease are not dreams either, but 606 stands in a class by itself.

The search in the tar barrel has resulted in many kind products. The healing antiseptics, as the chloramines; the complicated mercury added radicals to chrome carriers—for these we are duly thankful. We accept with gratitude odors which surpass those of nature's garden-colors, the like of which never were seen prior to the studies of Perkin. We use coal-tar products for the alleviation of pain; for anesthesia; as substitutes for rare or otherwise costly natural products. Color—all color.

On the other side of the ledger we have the unkind products. Explosives, poison gas, these and a host of by-products which upset natural economy between nations and favor the technicians—are likewise products of the same tar barrel. The less said of these the better.

To-day, then, no matter what your field of endeavor—no matter what your major interest—you are influenced by the discovery of the first coal tar color. I defy you to touch anything within reach of your hand which is not influenced since your grandfather's time because William Henry Perkin uncovered the royal purple. The ink which flows from the pen, the color of your tie, the saccharin in the gum or candy pellet you still nurse between your jaws—and on and on—each has been changed because Perkin went home on a vacation and did not throw away the evil result of an experiment.

How can one guess what to-morrow will bring forth from the tar barrel. It is claimed that after 606 we had 914, but that hundreds of other chemical combinations remain to be made which the color genius of Ehrlich wrote on paper. One of them may further revolutionize the healing art. A student of to-day may yet stand forth with still weightier dis-

coveries than the two youths we have named—Perkin and Ehrlich. That scourge of the human race, cancer, may yet yield to coal-tar chemical miracles.

We must mention briefly that coal tar has been offered as a cause for cancer. Certain chemical quotients of coal tar applied to the tail of the experimental rat have already produced cancer reactions. Certain coal tars are known to produce other irritations not as serious as cancer but unsightly and undesirable. We rarely have skin and mucous membrane irritations from the color additions in food, drugs and cosmetics. We have the rarity of lip stick dermatitis which is so welcomed by the reformers and prohibitionists of cosmetics. We likewise have the unfortunate general reactions of certain individuals to other coal tars taken by mouth to relieve disease. In medical practice, we group these rare ill results under the term of "allergy" which is mysterious until defined as altered reactivity. Then we know that the name allergy doesn't explain anything! It only gives a Latin name and places the whole matter into the oblivion of a pigeon-hole. But allergy doesn't remain pigeon-holed for long. Each new piece of evidence drags the entire matter forth into the light of court of law if not into sunlight and rational laboratory procedures.

There is no explanation for allergy which really explains. We have discussed the questions of allergy often, and the matter remains one for individual opinion.

The interrelationship between dermatitis and allergy is also one of individual opinion, although subject to some experimental study in addition to philosophical discussion. Coal-tar colors may act in the production of each. A generalized exfoliation of the skin of the recipient of a dose of arsphenamin is sufficiently terrifying and illness-producing without burdening patient or physician with the added excitement of classification—dermatitis or allergy. It is back to altered reactivity. Fortunately, much arsphenamin is given without the dermatitis. But it is an example of color injury to man.

Color adds beauty to life; coal-tar chemistry foundation of color adds to life itself except when it takes life. But perhaps there has been compensation. Although it is true enough that had there been no coal-tar chemistry, we may not have had a world war, it is equally true that had we not had salvarsan, the world made safe for civilization may have been victim to syphilization!

A SOLUTION FOR LAND TRANSFER DIFFICULTIES

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THE methods prevalent throughout the United States for the determination of title of real property are so cumbersome and inexact that in recent years many persons whose work has brought them in contact with real estate transfers have given considerable thought to their improvement. The methods not only unduly increase the expense of transfer of title but frequently seriously delay the consummation of sales. With such methods in use the transfer of real estate involves difficulties never encountered in the transfer of other forms of wealth. Where property has changed hands frequently within a short time or where many years have elapsed without a recorded transfer, titles often become hopelessly involved. Land surveyors, title examiners and realtors are in agreement that these methods should be completely revised. In an effort to mitigate some of these troubles many state legislatures have enacted or are considering the Torrens system of land registration. This system, to be discussed later, offers a splendid solution to some of these difficulties; but while such a system is excellent as far as it goes, it can never attain the objective desired unless other important changes in the methods accompany it.

Under the present methods of proving title, it is imperative that *two distinct studies* be made of conditions affecting the parcel of land in question. The first study is a search covering many recorded documents, which is colloquially known as a title search, tracing the title from its source and examining the records for liens against the property. Such a search is time-consuming and expensive, and unless made with great care and good judgment, errors frequently occur.

The second study, of equal importance with the first but seldom given much thought, is the necessary careful instrumental examination of conditions on the ground. It is essential to determine the positions of landmarks and established boundary lines actually existing, and to compare the positions of such landmarks with the descriptions of the properties found in the recorded deeds. Such an examination enlarges in scope as the various partitions of land are studied while working back to the first partition from the original tract. It calls for a complete and accurate survey of existing boundary marks over a considerable area surrounding the property in question as the location of each boundary line is dependent on the location of others in the neighborhood. Not only must the location and shape of the parcel be judged by its own description, but its size, location, and shape with respect to that of neighboring properties must be carefully considered. It is obvious that such an examination parallels very closely a search of title, except that due to the restrictions of geometrical requirements, a thorough study of adjoining and surrounding properties is also required. Due to the necessity for this comprehensive program of accurate field surveying, requiring the services of several trained men and usually covering the entire area of the original tract, the expense of a proper examination of this kind is altogether too great to be charged against one particular parcel of land.

Obviously, the title search and land examination necessary for one property is adaptable, with slight modifications, to all properties within the original tract. For this reason it is customary for organizations engaged in frequent title

search to maintain a list of abstracts of title and for land surveyors to keep files of survey records referring to each original tract. When such records have been collected the cost of obtaining them can be spread over all the examinations and surveys made throughout the area, and each client receives the benefit of the complete work.

But unfortunately no legal recognition is given to such an arrangement, and therefore no control exists for the regulation of this work. The individual is not protected against spurious surveys which appear to be made with care, but in fact are not based on the necessary complete investigation described and which because of this lack of thoroughness are offered at a lower cost, than would be charged for an accurate and complete survey made by a reputable surveyor. Also in the search of the documents and in the examination of the ground, personal opinions must be relied upon. It is not clearly realized that although surveying is an exact art, in locating land boundaries so many inconsistencies arise that judgment is more important than skill. Both the title examiner and the land surveyor are forced to make assertions to their clients as to what they believe would be the result of a court decree. The client demands this, as the cost of such a decree would be out of all proportion to the matter involved. Also, when either the examiner or the surveyor is of the opinion that a court decree is necessary, a cloud is cast on the title of the property in question, and due to the fear of loss of title or the excessive costs of court procedure, no steps are taken to clear the title and the parcel may become practically without a market and its value may deteriorate as the owner does not wish to risk improvements on it. A clouded title for a parcel of land in a locality also reduces the value of adjacent property as its ultimate disposition is usually a matter of conjecture.

If legal recognition were immediately given to the decisions of the examiner and the land surveyor (after proper judicial review), and the actual title certified by the court with reference to a definite, legally recognized system of marking the boundaries, the chief cause of clouded titles would be eliminated.

The Torrens system, which has been adopted in one form or another in some twenty-two states and territories, provides a simplified and business-like method for the establishment of titles and eliminates repeated searches of recorded documents. To quote from a "Manual of Torrens Procedure" by R. G. Patton and C. G. Patton, " 'The principle of this system is the registration of the title to land instead of registering, as the old system requires, evidence of such title' Chief Justice Start in State vs. Mitchell, (1902)85 Minn. 437, 89, N.W." In a word, the Torrens system provides for a definite court procedure which results in a court decree granting a certificate of title upon which all subsequent changes affecting the title of a parcel must be recorded. The certificate thus becomes sole and complete evidence of title and future title searches are confined to mere examination of the certificate, together with certain checks of recent tax liens.

It must be noted, however, that the Torrens system eliminates only the difficulties and inaccuracies of the title search, it does *not* eliminate the necessity for an extensive examination of the ground. A word of caution would therefore seem appropriate as a warning to those state legislatures considering the adoption of the Torrens Law. Historically the method was developed from a system of ship registration which had been found to be most successful. But the great difference in this connection between ships and real estate lies in the fact that it is a simple matter to identify a certain vessel and to prove its existence, but it is very difficult indeed to identify and determine land boundaries, or to even prove that a parcel of land exists at all.

Astonishment has often been expressed that persons will frequently avail themselves of the services of a title company rather than rely upon the Torrens system, backed as it usually is by a guarantee of title by the state and an assurance against loss provided by an insurance fund made available from the state treasury. The reason becomes clear when it is understood that the title company offers a prospective client a far greater service than is provided by the usual Torrens Law. A good title company not only maintains accurate title record information but employs, or retains, competent surveyors whose office records include complete survey information in the areas in which they work. The client is assured that when a title company offers a guarantee of title, proper documentary search has been made and a complete examination of the ground in the light of the descriptions contained in recorded deeds has been made by a competent surveyor.

The above-mentioned defect in the Torrens system has so handicapped its operation that many regard it with suspicion or scorn. It has even been attacked as a raid on the state treasury for cheap title insurance.

In the light of the foregoing let us consider the necessary elements of a proper system to prove title:

(1) All documents bearing on the title must be studied by a competent examiner. He should weigh the evidence of such documents, assure himself that nothing has been overlooked and make a report of his findings.

(2a) A complete preliminary instrumental survey must be made by a competent land surveyor based on *enduring legally recognized monuments* and referencing all existing landmarks to these monuments.

The chief consideration in the above requirement which is most difficult to obtain is the durability of monuments. If a monument is to be enduring it must be part of a system of monuments, the relative positions of which have been determined by precise surveys. In other words, it must be part of an accurate, well-designed system of survey control. Under these conditions any monument in the system can be reset when disturbed or lost by a survey extended from any two other monuments in the system. If a city survey exists, this system will serve, but by far the best solution is to connect the monuments with the fundamental triangulation net of the U. S. Coast and Geodetic Survey. When local surveys are tied to these marks, such survey can be reproduced precisely with the certainty that the original initial point was used. The State Systems of Plane Coordinates recently introduced by the U. S. Coast and Geodetic Survey provides a means of facilitating such connections.[1]

(2b) The land surveyor should weigh the evidence produced by his survey in the light of descriptions in recorded deeds, assure himself that all the evidence has been gathered and that the survey is made in accordance with recognized standards, and make a report of his findings.

(3) These reports should be reviewed by competent state officials, preferably by a judge familiar with such matters, and an experienced surveyor-general. Any further evidence thought necessary by the reviewers should be obtained.

(4) The matter should then be made the subject of a court proceeding to which are cited all interested parties. The court should issue a decree stating the condition of the title and a description of the boundaries with respect to the enduring

[1] The system of plane coordinates established by the U. S. Coast and Geodetic Survey for New Jersey was given official approval by an act of the legislature of that State in 1935, and at the present time bills of similar purport have been introduced in the legislature of other states. Such a law was enacted recently in Pennsylvania and in New York a bill of this kind is awaiting the governor's signature.

monuments previously described in paragraph 2a.

(5) A certificate should be issued as a corollary to the decree which would be sole evidence of title and location of the boundaries. It should be the duty of the court to see that this certificate be preserved and nothing affecting title or position of boundaries should be recognized unless recorded on the certificate.

In other words, the Torrens system handled by a special Land Court which includes the office of a surveyor-general, together with the use for property description of a legally recognized State Plane Coordinate system, is the goal to be reached.

The beauty of this system lies in its finality. By its legal approval of the findings of the examiner and of the findings of the surveyor, and the recognition of boundaries and monuments used, it fixes title and location of a parcel of land once and for all time and it removes forever the necessity for repetition of this work. The costs of such a system could therefore be fairly charged, not only to the original owner but also to subsequent buyers of this registered land, thus making an equitable distribution thereof. The value of such property is so enhanced by this system that future owners would be glad to pay a transfer tax for the benefits obtained.

In the State of Massachusetts, a close approximation to this system has been reached. In this state, a Land Court, consisting of three judges who sit in various parts of the Commonwealth, has been instituted with jurisdiction over nearly all forms of litigation having to do with real estate. The judges of this court, due to their specialization, have become experts in real property law. This is a great advantage in itself as a large percentage of such actions are uncontested. When this court was established, an able land surveyor was appointed as an assistant to the recorder and his advice and counsel has resulted in sound practices with respect to the location of the property boundaries.

He reviews the work of the surveyor, who makes the original determination of survey data and is responsible to the court for the accuracy of the survey together with the location of the lines shown. He is careful to see that sufficient information has been obtained and that no pertinent fact has been omitted. Thus when the court makes its decree it has before it not only complete information obtained by the title examiner but complete and accurate survey information as to the location of the various property lines and landmarks. When a court decree is issued, the engineer of the court is responsible for the proper marking of the property on the ground so that the lines decreed can be located at any time. He is careful to see that the marks are permanent and properly interconnected by surveys so that each becomes a witness to the other. When state coordinate monuments are available, survey connection is made with them which still further increases the permanence of the decreed lines. In his office a scale drawing is made up for each parcel showing the decreed boundaries and complete survey information including that for landmarks. This drawing becomes a part of the certificate of title and assures the owner not only of title but of the location of his holdings.

It is suggested that when an act establishing a Torrens system is under consideration, the pattern of the Massachusetts law be adhered to, modified to include the appointment of a surveyor-general, who shall advise the court in matters relating to facts determinable by instrumental surveys and be responsible to the court for the proper marking of the property on the ground by a sufficient number of enduring monuments, together with the elimination of conflicts caused by geometrical requirements.

ORGANIC THEORY OF THE STATE

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I

It is apparent to most thoughtful people to-day that the political and economic machinery of American democracy must be overhauled, if our democratic institutions are to survive and are to meet the needs of the future. Economists, sociologists and practical politicians, however, are far from being in agreement as to the type of revision best suited to American needs. The greatest handicap at the present time is the lack of a basic philosophy on which all can agree. I, therefore, venture the opinion that the most reliable guide to an impartial and successful overhauling of our democratic institutions would be the political ideals deduced from the economic perfections of the human body.

There is nothing new or revolutionary in this suggestion. It would merely mean renewed faith in an ancient religious or philosophical concept, the modernization of an ancient biological doctrine and its readoption as an impartial yard-stick in social engineering. This ancient philosophical concept is known technically as the functional or organic theory of the social order.

II

The organic theory of the state pictures the politico-economic state as a living organism, a large-scale manifestation of the same basic biological laws as those studied to-day by means of the microscope and test-tube. Thus pictured, political, economic and social institutions become literally organs of the body-politic or functions of the economic order, in much the same way that the heart is an organ performing a necessary function in the human body.

If all this is true, it logically follows that translation of social problems into homologous problems in human pathology or human physiology would automatically suggest ideal solutions of these problems, solutions planned by creative intelligence or, in more modern language, solutions perfected by ten million years of organic evolution.

In somewhat different language, the organic theory of the state assumes that social planning is a biological problem, not a mere question of engineering efficiency. In fact, the theory even suggests that biological efficiency and engineering efficiency may be incomparable with each other. The organic theory further assumes that the best guide to social reform would be the creative intelligence or evolutionary wisdom manifest in the solution of identical problems in the human tissue-complex.

Historians tell us that this theory and method of application had their origin in Greek philosophy, four centuries before the beginning of the Christian era. This pagan theory was afterwards translated into Christian terminology. Thus translated the organic theory of the state became part of the official doctrine of the medieval Christian Church. During the thirteenth, fourteenth and fifteenth centuries, for example, it was applied by such leaders as Thomas Aquinas to the solution of the major political problems of that time. Reasoning from the erroneous anatomical and physiological knowledge of their time, they deduced the doctrines of the "divine rights of kings" and of the superiority of the church over the civil authority of the state.

III

No one will deny that modernization and readoption of this ancient philosophy would be of academic interest. It, how-

ever, would be without practical value, unless it can be shown that application of the biological yardstick suggests new ideas or new points of view in political science not readily drawn from historical data or statistical evidence. In order to test this possibility, I have selected an extremely simple biological problem, comparison of the American theory of state rights with the physiological ideal.

The American Constitution makes provision for two types of national organization. First, there is the normal or peace-time integration of the states, a union or partnership of free and independent states, each state retaining full sovereignty over all problems arising within its own borders, except such powers and duties as are formally delegated to the national government. Second, there is provision for an emergency or war-time integration, an automatic change of our union into a totalitarian state under the dictatorship of the national political machinery. On the passing of the emergency this emergency totalitarian state automatically reverts to a peace-time democracy.

IV

In the human body there are provisions for the same two types of organization, but with one essential difference. The peace-time democracy and war-time dictatorship do not alternate with each other as in our national government, but are operative simultaneously and are very closely integrated with each other. The skeletal muscles, for example, and other parts reacting directly with or against external environmental factors have lost their individual autonomy and are under the constant dictatorship of the central nervous system. The essential internal or domestic functions of the body, however, have to a large extent retained their individual autonomy and are organized as a peace-time democracy, with minimal dependence on centralized neurologic authority.

This, however, is far from being a union of free and independent organs. It is essentially a partnership of interdependent organs, in which each organ delegates part of its local sovereignty to related tissues in other parts of the body. Thus, the heart, removed from the animal body and attached to a proper perfusion apparatus, will automatically adjust its rate, volume and strength of contraction so as to meet its own minimum needs, through the coronary circulation. Under these conditions the heart exercises full sovereignty over all problems arising within its own borders.

Returned to the animal body, however, part of this cardiac sovereignty is delegated to the neighboring tissues of the thoracic cavity, and part even to more distant organs of pertinent function. Thus, part of cardiac control is vested in the far distant kidney, which under certain conditions, in order to insure its own circulatory needs, can cause the circulatory system to double its normal work. Recent investigators have shown that the resulting arterial hypertension or partial dictatorship of the kidney over circulatory functions is not mediated through the central nervous system, but is effected by means of some wholly unknown decentralized chemical hormone.

V

In place of attempting to describe this integrating pattern in greater detail, it may best serve our purpose if I should outline the necessary revisions in our present political machinery, if the United States were reorganized to conform with the physiological ideal. Thus reorganized, California, for example, would still retain full sovereignty over all problems arising within its own borders. Its executive, judicial and lower legislative machinery would remain unchanged, except that some type of proportional representation instead of our present majority rule would be more nearly in accord with the biological pattern.

The California senate, however, would be radically revised. First, state senators would not be elected, as at present, to represent geographical areas, but would be selected or appointed by the major cultural and economic groups of California as a whole. Second, the state senate would be enriched by one or more regional senators, elected or appointed by each of the neighboring states of the Pacific Slope, with a smaller number of senators selected by more distant states or groups of states of similar cultural or economic interests. Finally, California would receive one or more environmental senators from Canada, Mexico, South America and the Orient. In return, California would elect or appoint one or more state senators to represent its own interests in the higher legislative branches of every other major state of the American Union. The result would be a union of free but formally interdependent states, the interdependence being symbolized by interlocking legislative machinery.

VI

A biologist, of course, is not concerned with the political feasibility of any plan suggested by the physiological model. The above plan, however, illustrates the type of ideas drawn from modern biological analogies. Incidentally, it would solve a controversial question of the present time—what to do with our state senate. Evolutionary wisdom rarely discards a superfluous organ, provided it is possible to transform it into a useful function.

Now picture a further evolution of this California plan. The United States Senate changed to represent the major cultural and economic groups of America as a whole and enriched by one or more environmental senators appointed or elected by Canada, Mexico, Brazil, Argentina, the principal European powers and the Orient. In return, two or more American senators sitting in the House of Lords and in the equivalent councils or legislative branches of other major nations. An international physiological integration, though interlocking legislative machinery, making superfluous the present biological monstrosity the League of Nations. Until some such form of decentralized international integration is worked out, world peace will remain a biological improbability.

VII

The limits of this paper will permit only brief mention of one or more of the more complex social problems for which logical and consistent solutions can be suggested by the biological yardstick. One of the most interesting of these is the problem of capital and labor. This may be studied by means of analogies with capitalistic tissues, labor tissues and consumer functions in the human body.

Two facts are soon apparent from such a study: (1) Both the capitalistic system and the profit-motive are endorsed by evolutionary wisdom, and (2) the present American, German, Italian and Russian systems of industrial relationships are all equally at variance with the biological ideal. The nearest approach to the physiological ideal thus far developed in any modern civilization is the Decentralized Cooperative Democracy now in course of apparently successful evolution in Scandinavia.

An experimental pathologist, however, would emphasize certain inherent dangers in the cooperative movement, if planned or allowed to develop in such a way as to reduce individual competence and initiative. Physiological cooperation of human tissues is essentially competitive in nature, constantly training the aggressive efficiency of individual cells, organs and functions. Non-competitive cooperation, however, can be produced under certain experimental conditions. Such parasitic cooperation, however, inevitably leads to atrophy of one or more of the non-competitive tissues.

THE CAUSES OF CANCER[1]

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THE development of cancer in an organism consists in the transformation of certain previously normal adult or embryonal cells into cells which grow more actively and in some cases also carry out more active movements. They do not, therefore, respect the boundaries of the surrounding tissues with which under normal conditions they are equilibrized in a definite way. These transformed cells may also invade vessels and thus cause metastases at distant places. At the same time they undergo certain alterations in their metabolism, among which the changes in carbohydrate metabolism have perhaps been best studied. As far as we know, cells which have once undergone this change always remain cancerous; they may be destroyed or otherwise eliminated, but they do not ever return to their normal mode of life; they remain in an over-active, stimulated condition as long as they live.

The cancer problem concerns, then, the question as to why cells undergo these changes in their mode of growth and in metabolism. A complete answer would presuppose a complete understanding of the processes of normal growth, normal tissue movements, and normal cell metabolism. In the wider and deeper sense the cancer problem is therefore a problem of tissue physiology and will progress concurrently with the latter science. But if we restrict the cancer problem to a study of the conditions under which normal tissues undergo these abnormal and apparently irreversible changes, our knowledge is more definite, although even then certain important defects in our knowledge still remain.

In order to present the main facts known concerning this transformation of normal into cancerous tissue, we shall cite a few typical examples of animal cancers in which the causes of cancerous growth have been more thoroughly investigated. It has been shown that the development of carcinoma of the mammary gland in mice can be prevented by eliminating at an early period, by means of ovariectomy, the action of ovarian hormones, in particular, oestrin, on the mammary gland tissue. The earlier in the life of the animal this hormone action has been removed, the larger is the number of female mice in which the occurrence of cancer is prevented. We may therefore conclude that oestrin is largely responsible for the development of mammary cancer in mice; this hormone apparently acts by inducing rhythmic growth processes in the mammary gland tissue during proestrus and oestrus, and during pregnancy. This conclusion can be confirmed by injecting large amounts of oestrin into animals over long periods

[1] It may be of interest to compare with this paper on "The Causes of Cancer," a paper by the writer on "General Problems and Tendencies in Cancer Research which appeared in *Science*, March 3, 1916, Vol. 43, p. 293. References to the literature up to the year 1936 may be found in an article by the author on "The Interaction between Hereditary and Stimulating Factors in the Origin of Cancer" in the *Acta of the International Union against Cancer*, 2: 148, 1937. More recent papers to which reference is made are the following: Peyton Rous, *Am. Jour. Cancer*, 1936, Vol. 38, p. 233; R. A. Moore and R. H. Melchionna, *Am. Jour. Cancer*, 1937, Vol. 30, p. 73; J. Furth and C. Breedis, *Archives of Pathol.*, 1937, Vol. 24, p. 281; J. J. Bittner, *Jour. of Heredity*, 1937, Vol. 28, p. 363; V. Suntzeff, E. L. Burns, Marian Moskop and Leo Loeb, *Am. Jour. Cancer*, 1938, Vol. 32, p. 256.

of time; under these conditions the number of mice which develop breast cancer increases and even male mice can be made to acquire this type of cancer.

But there are still other factors active in the development of mammary gland carcinomas. In addition to the stimulating action of the hormone a second factor comes into play, which is transmitted by heredity from generation to generation in certain families and strains of mice. In some strains this kind of cancer almost never occurs, while in others every female mouse becomes cancerous if it reaches a given age. It has been maintained that a single recessive gene is responsible for the hereditary transmission of this and other tumors. However, this is not the case; it has been shown that the hereditary tendency of the mother to acquire mammary gland cancer is more important in determining the development of mammary gland carcinoma in the offspring than the hereditary constitution of the father, and according to the recent experiments of Bittner there is some indication that the milk of the mother transmits some kind of cancer-inducing factor to the child. In strains with a high hereditary cancer incidence the milk of the mother seems to contain this factor more often, or in a more effective degree, than in strains with a low cancer incidence.

However, this statement applies only as far as cancer of the mammary gland is concerned. Mice may also, as a result of long-continued injections of oestrogenic hormones, develop precancerous and carcinoma-like lesions in vagina and cervix, especially at the portio; in this case the hereditary factors which help to determine the formation of mammary gland carcinoma are lacking or different; oestrogenic hormones evidently induce the development of cancer in those organs in which they call forth long-continued or often repeated growth processes. At the time of each oestrus, oestrogen induces proliferative changes in mammary gland as well as in vagina and cervix.

But in addition to carcinoma, sarcoma may develop in some mice which have been injected with oestrogenic hormones over long periods of time and this usually occurs near the place which has been chosen for the injections. Sarcoma formation may, however, be induced also by the injection of substances which do not cause carcinomatous growth in the mammary gland and vagina, such as luteal hormones and even solutions which contain neither ovarian hormones nor one of the common cancerigenic chemical compounds. The factors underlying sarcoma formation are therefore less specific than those causing carcinoma in mammary gland or vagina and cervix. Whether it is the mechanical injury caused by the injection of the fluid and the regenerative growth processes which follow this injury, or whether chemical factors of a less specific nature are involved, is as yet undecided. It is well known that long-continued irritation of certain tissues leading to often repeated attempts at wound healing, and therefore to regenerative growth processes, may in the end induce the development of cancer. We may then state that often repeated regenerative growth processes and hormones may cause cancer.

But there are still other kinds of stimuli which have similar effects. Thus certain metazoic parasites may change normal tissue into cancerous tissue. Bilharzia infecting the human bladder may here first produce a benign papilloma, and this gradually passes into carcinoma. In general, benign tumors—exclusive of malformations or of the results of inflammatory alterations—in particular various types of adenoma, papilloma, and probably also myoma, fibroma and angioma, may be considered as potential transition states between normal tissues and cancers, and all types of such transitions may occur although, as a rule, these

growths do not undergo this extreme change.

There are metazoic parasites which may cause cancer in the liver of the rat, and still others have been held responsible for the development of cancer in the fore-stomach of rats. The active stimuli in these cases are presumably chemical in nature, but the participation of mechanical factors can not be definitely excluded. Roentgen rays, radium and ultraviolet rays also may produce cancers, carcinoma as well as sarcoma; which of these two kinds of tumors is produced depends largely upon the tissue upon which these agencies act. We have already mentioned the fact that mechanical irritations which induce long-continued regenerative growth processes may eventuate in cancer.

Many years ago Yamagiwa and Ishikawa discovered that the application of tar extending over relatively long periods of time may lead to cancerous transformations of the exposed rabbit skin. This malignant change passes through an apparently benign stage of wart formation. Subsequent investigations, especially by Kennaway and Cook, have shown that certain hydrocarbons related to substances found in tar are very effective in inducing the development of cancer. Carcinoma, and also sarcoma, may thus originate in a relatively short time and in a large percentage of the mice exposed to their influence. The most active of these substances are 1: 2: 5: 6-dibenzanthracene, 1: 2-benzpyrene, and methylcholanthrene. At first it was thought that a specific chemical constitution could be associated with this cancerigenic action, but more recent studies have constantly added to the number of effective substances and it has been found that the latter may vary greatly in their chemical constitution. However, notwithstanding this relative lack of chemical specificity, it is noted that if we examine a single cancerigenic substance by itself, the nature and position of certain chemical groups determine its effectiveness. Furthermore, it has been shown that while in general all the tissues capable of growth on which these substances act may assume malignant growth, some of these compounds exhibit a certain selectiveness for definite organs; this selectiveness depends presumably upon the place where such a substance is retained for a sufficient length of time, especially during the process of its excretion.

In all the examples of experimental, and also of spontaneous cancer which we have mentioned so far, a definite stimulus could be discovered which was essential for the development of the tumor. In some cases it can be made very probable that even a combination of stimuli is responsible for this transformation of normal into cancerous tissue. Thus in the case of the experimental carcinoma-like changes of the vagina, portio and cervix of the mouse it can be shown that, in addition to the action of oestrogenic hormone, a mechanical injury to the surface epithelium due to friction exerts a stimulation on the epithelium, which very likely favors the initiation of cancerous growth. The same holds good presumably also in other cases. The localized effect of these mechanical factors would explain why, notwithstanding the fact that the hormone acts on the whole mucous membrane, carcinoma as a rule develops only in certain restricted areas. However while, as stated, the place of carcinoma formation is more or less localized and not general, nevertheless in vagina and cervix, as well as in mammary gland, it can be demonstrated that a malignant tumor does not start from a single transformed cell, as is still assumed by a number of investigators, but from larger structures such as ducts and acini, or certain areas of the surface epithelium. But gradually with continuing and increasing stimulation the growth

of these experimental cancers may extend to wider and wider areas and larger numbers of cancerous foci develop, until in the end the time can be foreseen when the cancerous change will become generalized. Observations such as these make it very improbable that the growth of malignant tumors depends upon gene mutations in somatic cells, to which it has been and still is referred by a number of pathologists. It is not very well conceivable that such mutations would occur simultaneously, or almost simultaneously, in so large a number of cells.

We have discussed so far the significance of stimuli in the origin of cancer. Such stimuli can be discovered in experimental cancers and they can also be shown to exist, or can at least be suspected in the large majority of spontaneous cancers in man, especially those developing in adults. However, there are other kinds of cancers in which it is not possible to detect such a stimulus which could be held responsible for their formation. This applies especially to those cancers whose origin can be traced back to embryonal stages. We must assume that in such cases constitutional factors, which are often or perhaps always hereditary, induce certain abnormalities in the embryonal development of a given tissue or organ; unknown stimuli, perhaps substances produced in the ordinary metabolism, may then transform as plastic a material as embryonal cells, endowed with a strong growth tendency, into cancerous tissues. Mixed tumors of the kidney, glioma of the eye, may be cited as examples of such cancers in which apparently constitutional-hereditary factors greatly preponderate over growth stimuli.

If we extend the definition of such constitutional-hereditary factors still further, so that they include not only family and individual but also strain and species constitutions, they can be shown to play an important rôle in all kinds of cancers. Thus carcinoma of the mammary gland is very common among many families of mice, but it occurs hardly at all in guinea pigs. If, on the other hand, we consider only families or individuals in a given species, heredity plays a very unequal rôle in different types of cancer. It has great significance in carcinoma of the breast of mice; it is much less significant and different in nature in cancer of the cervix and vagina of mice, if it exists here at all. As we have already mentioned, it is very important in the origin of certain embryonal cancers in the human species. In those types of cancer in which a hereditary tendency to the development of cancer plays a rôle, a deficiency in hereditary tendency in an individual, family or strain means that the amount of stimulation which it is necessary to apply in order to produce cancer is greater than in an individual, family or strain in which this tendency is great. An inverse quantitative relationship exists approximately between the degree of hereditary predisposition and the amount of stimulation that is required in order to induce cancer. As far as we know, this hereditary predisposition applies in each instance to a specific organ or tissue, and not, as a rule, to all the organs and tissues of the individual uniformly.

As to the nature of this hereditary predisposition, in some cases it may consist in a tendency to a certain malformation, in other cases in the degree of sensitiveness and readiness to respond to stimuli; in still other cases the hereditary tendency to acquire a certain disease which causes injury and subsequently regenerative processes in some organs may secondarily cause the predisposition to the development of cancer. In other instances perhaps the transmission of an agent may be involved in it. As mentioned above, there may also be differences in the mode of inheritance in different kinds of cancer; in some it may be by way of certain genes, in others by

way of the cytoplasm of the egg. This applies to tumors which may arise in different places in the same individual, as, for instance, in mammary gland and vagina-cervix of a mouse. In the inheritance of mammary gland cancer of the mouse in which the constitution of the mother predominates over that of the father, this difference in the significance of the two parents seems to be due largely or entirely to a factor transmitted by the mother's milk to the suckling young. On the other hand, in leukemia of mice, which may be conceived of as a cancer of the leucocyte—forming organs, the hereditary constitution of the mother likewise preponderates over that of the father, but in this case this condition does not, according to MacDowell and Richter, depend upon the transmission of an agent by the mother's milk. Considering all these circumstances it does not seem promising to attempt an eradication of cancer, or even a marked diminution in its incidence, by influencing the gene-composition of human families by means of selective breeding. The avoidance of stimulations leading to cancerous transformation of normal tissues is probably a much more hopeful procedure.

We may conclude that although the disease as such, as a rule, is not due to a change in a gene or chromosome of a somatic cell, the hereditary condition which makes certain organs or tissues prone to become cancerous may be due to mutations in germ cells, and this may explain why, in some cases, two sisters to whom the same mutation has been transmitted may both be affected by the same rare kind of cancer. We have in such instances in all probability to deal with hereditary changes transmitted by the germ cells and affecting the hereditary predisposition to the development of cancer in certain tissues.

While the cancers developing on an embryonal basis appear often in early life, the ordinary tumors originating in adult tissues are seen usually in older individuals. This preference for older organisms is noted in human as well as in animal cancers. It is due to the fact that the older the individual is, the longer a particular cancerigenic stimulus has had a chance to act; but in addition it is probable that changes in the constitution of various tissues, which are characteristic of old age, are favorable to the development of abnormal proliferations. This applies, for instance, to the human skin. However, in animals as well as in man, typical cancers of non-embryonal tissues may be observed in rather young individuals; we must assume that in such cases a threshold quantity of stimulation, sufficient for the inherited constitution of a certain tissue, has had a chance to become effective.

All the factors leading to the development of cancer seem then, directly or indirectly, to stimulate growth processes; the tendency to squamous cell metaplasia in tissues normally lined with cylindrical epithelium which is so frequently observed in precancerous conditions, represents probably an early stage of growth stimulation, and such changes are also induced by cancerigenic hydrocarbons in some organs; this has recently been observed after a series of injections of 1:2-benzpyrene in the prostate of the rat by Moore and Melchionna.

We may then conceive of cancer as the end-result of an amount of stimulation of tissue growth exerted during a certain length of time and exceeding a definite threshold quantity still compatible with normal activity, this quantity depending upon the constitutionally and often hereditarily determined receptivity of these tissues to a given type of stimulation. It may be assumed that as the result of such constant growth processes or of certain changes associated with the latter, the normal tissue equilibrium becomes in the end irreversibly altered, perhaps owing

to the rhythmic new formation within the cells of a substance which induces cell multiplication and initiates definite metabolic changes, or to the formation of an increased quantity of such a substance. This new formation may be conceived of as due to a process comparable to autocatalysis.

This is one possible explanation of cancerous growth. However, there are certain experimental facts which introduced some complicating elements. Many years ago it was observed by Peyton Rous that, contrary to what takes place in mammalian cancers, where only transplantation of tumor cells into other animals of the same species or strain gives rise to new cancers, in certain avian sarcomas it is possible to separate from the tumor a material free of living cells, which on injection into another individual of the same or, as was found subsequently, under certain conditions even of foreign though related species, gives rise to a new tumor. This cell-free material is therefore the carrier of an agent which is able to induce normal cells with which it comes into contact to assume the character of sarcoma cells of a type similar to those from which the agent has been obtained. Of a similar nature to the agent of the Rous sarcomas in birds seems to be the virus which causes leukemia or leukosis in chickens. This conclusion is corroborated by the finding in recent years that the viruses causing these leukoses may also induce sarcoma formation in the chicken inoculated with such a particular virus. There are various distinct viruses which have these effects and the investigations of Furth and Breedis show that each virus has its specific tissue affinity and tends therefore to produce malignant transformation in a specific type of mesenchymatous cell. These agents or viruses can be propagated in tissue culture and a culture of a sarcoma cell may thus be the carrier of a virus which induces not only the development of a sarcoma but also of leukemia after injection of these cells into a fowl; conversely, a myeloblast multiplying in tissue culture may be the bearer of a virus which transmits to a chicken not only leukemia, but also a particular kind of sarcoma.

The significance of such viruses is, however, not limited to birds and to sarcoma formation. More recently Rous found in the case of a mammalian tissue that a virus may be concerned in the origin of carcinoma. In cotton-tail rabbits there occurs a papillomatous growth on the skin which, as Shope has shown, is caused by a virus. If such a virus-papilloma is made to develop in a domestic rabbit, it may assume the characteristics of a carcinoma. Furthermore, if injected into the veins of rabbits in which the skin has been irritated and induced to undergo growth processes by long-continued application of tar, this virus has a tendency to fix itself to the growing cells and to cause their transformation into cancerous cells. On the basis of these important investigations Rous suggested that the action of a virus may be a necessary condition in the origin of all kinds of cancerous growths, even in mammals.

In the kidney of leopard frogs Lucké has observed in recent years the occurrence of a peculiar kind of adeno-carcinoma, in the origin of which a virus may perhaps be concerned. Moreover, recent experiments to which we have already referred, seem to indicate that the milk of the mother may transfer to the suckling young an agent able to convert mammary gland tissue, previously stimulated by oestrogenic hormones over long periods of time, into carcinoma, even in strains which are hereditarily not predisposed to the formation of such tumors. In this connection we may also recall some experiments which date back more than thirty years, in which it was shown that contact with a mammary gland carcinoma may induce malignant growth in adjoining, formerly normal, connective

tissue or epithelial cells. These observations also could possibly be explained by the transfer of a virus from the cancerous to adjoining normal tissue.

We may then state that certain tumors are caused by viruses which act as growth stimulators. These stimuli differ from certain other stimuli not only in so far as they are due to substances present within the cells themselves, but also in that they can be readily transferred to other cells of the same kind, and especially to actively growing cells. Whether the cells functioning as carriers need the continued action of such intracellular growth stimulators for their cancerous proliferation, or whether, as is the case with other stimulating factors, they can be dispensed with after they have acted over a certain period of time, is not yet known; the latter alternative might hold, even if it should be definitely shown that the virus remains associated with the cancerous cells and exerts certain effects throughout the life of these cells. In this type of virus-cancer, hereditary constitutional factors also seem to play a rôle in addition to the stimulating factors. Thus, as mentioned above, the transformation of rabbit papilloma into carcinoma is apparently more readily accomplished in the domestic than in the cotton-tail rabbit. As to the nature of these viruses, some uncertainty remains. It is probable that neither the agent of the avian sarcomas nor the virus of the rabbit papilloma are living organisms in the ordinary meaning of this term; on the contrary, there are very strong indications that the latter, and perhaps also the former, are very complex protein substances. The manner in which they propagate in the cells has not been determined. In the case of the Rous sarcoma there is some evidence that these active substances are, at least in part, derived from the cells in which they functioned as growth stimuli.

There exists then, as far as we know at present, the possibility that these intracellular agents or viruses may not be so very different from the autocatalytically propagating intracellular growth stimuli which we have considered as perhaps representing the active factors in cancerous growth. While the number of cancers in which such an agent or virus can be separated from the tumor cells and become the initiators of new growths in tissues of the same kind is at present still very limited, as Rous has pointed out, it is conceivable that such agents or viruses may play a rôle in other types, and perhaps in all kinds of cancers, and the inability to separate these active substances from the cancer cells in the case of the large majority of all tumors may be due to secondary conditions. But even if this last mentioned interpretation should ultimately prove to be correct, all the other stimulating factors which have been shown to play a rôle in the origin of cancer would still retain their great significance undiminished; without their cooperation the agent or virus would not become active under natural conditions. We may for instance assume, on the basis of the experiments of Bittner, that even in the origin of mammary gland carcinoma of mice a virus or agent exists; but nevertheless, the older investigations remain valid. In these it was shown that after early removal of the action of ovarian hormones by means of ovariectomy the appearance of mammary gland cancer is prevented, and that a quantitative relation exists between the time during which these hormones are allowed to act and the number of individuals which are subsequently affected by cancer. Therefore, without the cooperation of hormones such an agent or virus would be impotent and unable to induce cancer formation. There are other observations which tend to confirm this conclusion. We would then have to assume that cancerous growth is due to the cooperation of various kinds of stimulating factors

and certain specific substances, acting as viruses and being perhaps related to the hypothetical autocatalytic growth promoters, the importance of which in the origin of cancer we suggested many years ago. Likewise the hereditary constitutional factors which we have mentioned as causes of cancer would retain their significance. However, as the matter stands at present, it must be conceded that there are some facts which seem to offer difficulties to the view that viruses play a rôle in all types of cancer, especially some of the findings relating to the action of hormones in the origin of certain cancers.

This short review of the principal data which concern the origin of cancer shows that some of the basic facts have been experimentally established. We are able by experimental means to induce certain cancers at will and also to prevent their appearance in a quantitatively graded manner. The conclusions based on these experimental investigations are in harmony with and confirmed by the clinical observations of human cancer. There still exist important questions which future investigators will have to answer, but on the whole, the uncertainties and problems that remain have narrowed down considerably. These unsolved problems in the origin of cancer can now be well defined, and, essentially, they turn around the two possible conceptions which we have discussed, namely, (1) the effect of irreversible metabolic changes taking place in cells and tissues under the influence of stimuli leading to intensive or long-continued growth processes acting in cooperation with hereditary constitutional factors, and (2) the effect of the interaction between these growth stimulating factors and viruses. Experimental methods seem now to be available for the further analysis of these alternatives.

This formulation of the problem seems to us to be in agreement with the principal facts established so far. Even if future findings should replace it by something more adequate, at least it enables us to arrange the data known at present in a convenient and consistent manner, and to bring order into an otherwise apparently unconnected array of facts. It does not pretend to satisfy requirements as far as the cancer problem in the wider sense is concerned, which latter is a part of the problems of tissue physiology in general.

GREAT ABILITIES: THEIR FREQUENCY, CAUSATION, DISCOVERY AND UTILIZATION[1]

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COMMON sense and psychology use freely a scaling of abilities from little to great or low to high. John, who can solve all the business problems that Richard can solve and many more besides, has, we say, more business ability or a higher degree of business ability than Richard. If A can do all the acts of skill as a carpenter that B can do and others that are harder to do, we say that A has more or higher ability as a carpenter. A typist who, working as well as she can, makes two mistakes per thousand opportunities has less ability than one who makes only one. A person whose product or service in any trade or profession satisfies very exacting tastes has more ability in that trade or profession than one who can satisfy only the less exacting.

It would be difficult to frame a rigorous definition of "great" or "high" as applied to abilities to solve problems, manage people, manipulate tools and materials, entertain the intelligent, entertain the dull, and all the other multifarious works of man. And it is not necessary, and probably not even advisable, to try to do so at present. But it is well to have in mind three notable varieties of such scaling. The first includes cases where the upper end of the scale denotes chiefly ability to do harder things; the second includes cases where the upper end of the scale denotes chiefly ability to do the same thing better, more exactly, more elegantly, more pleasingly, or otherwise in a more satisfactory manner; the third includes cases where the upper end denotes chiefly ability to do more things. The third is much less important than the others and is rarely dealt with by itself alone as a high ability. Our common-sense scales are usually mixtures or composites of these three, but relatively pure cases are those of high ability in (1) invention, (2) singing and (3) a certain lowly type of scholarship.

Common sense and all the social sciences freely assume the existence in men of qualities or traits or combinations thereof which are the causes of this, that and the other achievement. High musical ability is the ability to achieve so and so, to produce such and such a product, of harmony, pleasure in the listeners, etc. High entrepreneurial ability is the ability to hire materials, labor and tools and achieve a product that can be marketed at enough to pay the bills with a large surplus. But of what musical ability and entrepreneurial ability consist or how they are related to other abilities very little is known. Indeed, it would perhaps be preferable to replace such terms as executive ability, statesmanship, artistic ability, military genius, business ability and literary ability in each case by "the ability to produce so and so," until much more is known than now about their respective constitutions and affiliations. Something real and biological doubtless does correspond to each of these terms, but it may be different in different persons, and the trait in A which, along with other traits in him, gives him high military ability, may, along with other traits in B, make B a

[1] Based on an address before the American Academy of Arts and Sciences.

great captain of industry, or may, along with certain features of C, cause or permit C to be a great reformer.

Causation

The causation of specially high degrees of ability is, like everything else in human individual differences, the action of certain events or conditions upon the genes. If all fertilized ova were subjected to just the same series of events, the men who developed from these ova would still differ in their abilities to remember, think, sing, draw, jump, govern, make money or whatever else. If there were millions having as nearly the same genes as "identical" twins have, and if a hundred different trainings were applied to ten each of the thousand, the groups would differ more or less in such of their abilities as were sensitive to the trainings.

The causation of specially high degrees of ability differs in no fundamental respect from the causation of any stated degree of ability. The doctrine of the irrepressibility of genius by any environment, no matter how unfavorable (often attributed to Galton) is unsound, though very high inborn capacities do have a notable tendency to seek and find an environment that favors them and a training that heightens them. The potency of training may be very low, so that the most favorable versus the most unfavorable social conditions that a human organism could encounter in the United States to-day would make very little difference in the ability. It may be very high, so that an average status of the genes acted upon by the best possible series of events will produce a higher ability than the optimal status of the genes acted upon by the worst possible series of events. General intelligence and singing are cases where training is relatively weak as a cause of very high abilities. Ability in diagnosing diseases and ability in translating Indian languages are cases where it is relatively strong.

In many of the abilities which are called upon in our civilization to produce or serve, such as legal ability, medical ability, engineering ability, dramatic ability, executive ability or political ability, we have made arrangements whereby the training without which a person can hardly manifest very high ability is denied to those who have only mediocre or inferior genes in that respect. They can not get into medical schools or medical practice; they can not practice entertaining audiences; they can not, except rarely by nepotism, get training as executives or be elected to public office. So only the originally able receive the training and we can not tell how much or little the training could do for persons of low natural capacity. And in general, partly because we give training in relation to capacity and partly because individuals of high capacity seek and find opportunities for training, the two sorts of causation act together in close correlation.

A high capacity may fail to manifest itself in demonstrated ability, by lack of the adequate stimulus. Military ability may lie dormant if there are no wars. The ability to manage a great enterprise through a hierarchy of subordinates, each possessed of certain special abilities to a higher degree than that of the manager, could hardly show itself in a pastoral civilization.

In general, very high ability is due to (1) fairly favorable qualities in the genes plus (2) the favorable training which such genes select or create, plus (3) the favorable training which parents, friends and society in general provide. The first is primary and essential. Without it the second will be absent and the third will be largely unavailing. The three together, or sometimes the first and second without the third, raise the abil-

ity year by year to levels such that it can profit by more and more advanced training. If this is withheld at any level, the ability is kept from attaining still higher levels. So doubtless there were in Europe from 1600 to 1800 many thousand men who might have been as able rulers as Gustavus Adolphus or Frederick the Great, so far as the constitution of their genes is concerned. It is very desirable to provide adequate early training to persons of probably favorable inborn capacities, and to add to it in proportion as they profit from it. A point is soon reached in the case of high abilities for which there is an economic demand at which further training is provided almost automatically and the person is paid well to take it.

It is of some importance to know how much of the payments made for high abilities are in the nature of rent for the natural resources supplied by the genes and how much are to balance the time and money spent in acquiring mental capital by training. The latter is surely usually only a very small fraction of the total. Lawyers who receive $100,000 a year on the average from age forty to sixty-five, average less than a dozen years of training beyond the age of compulsory school attendance, and less than a score of hours a week of unpaid study from the end of this training to age forty. For the rest, such a one gets his training from work for which he is paid more and more liberally as his ability becomes known and increases. Estimating the cost of his training from 14 to 26 and his unpaid study from 26 to 40 very liberally, a single year's wages at 40 would pay for all.

In most business men of high ability the percentage chargeable to training is still less. Before the days of schools of business, such a one was paid for almost all his business training; and often the more valuable the experience was for him, the more he was paid for it. The man who received $100,000 as president, received, as vice-president, $40,000 and also the training which brought his ability status up to that demanded of a president.

What is indubitable in the case of high legal or managerial or financial ability is often equally true of doctors, engineers, artists, musicians, actors, literary men, orators, politicians, salesmen, speculators, confidence-men and burglars of great ability. They are often paid liberally for much of the training that is most valuable to them.

A word may be added, somewhat out of place, concerning the disutilities which men of very high abilities suffer by exercising their abilities and training to improve them when they could be playing golf, lying in bed, reading novels, dancing or enjoying wine, women and song. They are very small in comparison to the enjoyment which they get from their work. The ratio of satisfaction gained from exercise of the ability to satisfactions lost from lack of certain other enjoyments is in general higher the higher the ability. This is partly because of a fairly close correlation between ability and interest, and partly because the provision and exercise of a high ability bring self-approval, a sense of personal worth and social esteem.

Frequency

Common observation reveals that very high abilities are usually very rare. This holds good even when almost everybody has adequate early opportunities and when almost everybody who shows fairly high ability as a result of these early opportunities is eager to get more and is likely to be given more. Such is now the case, for example, with singing. The number of tenors as good as Caruso and Jean de Reszke will always be very small, unless some new discovery in the physi-

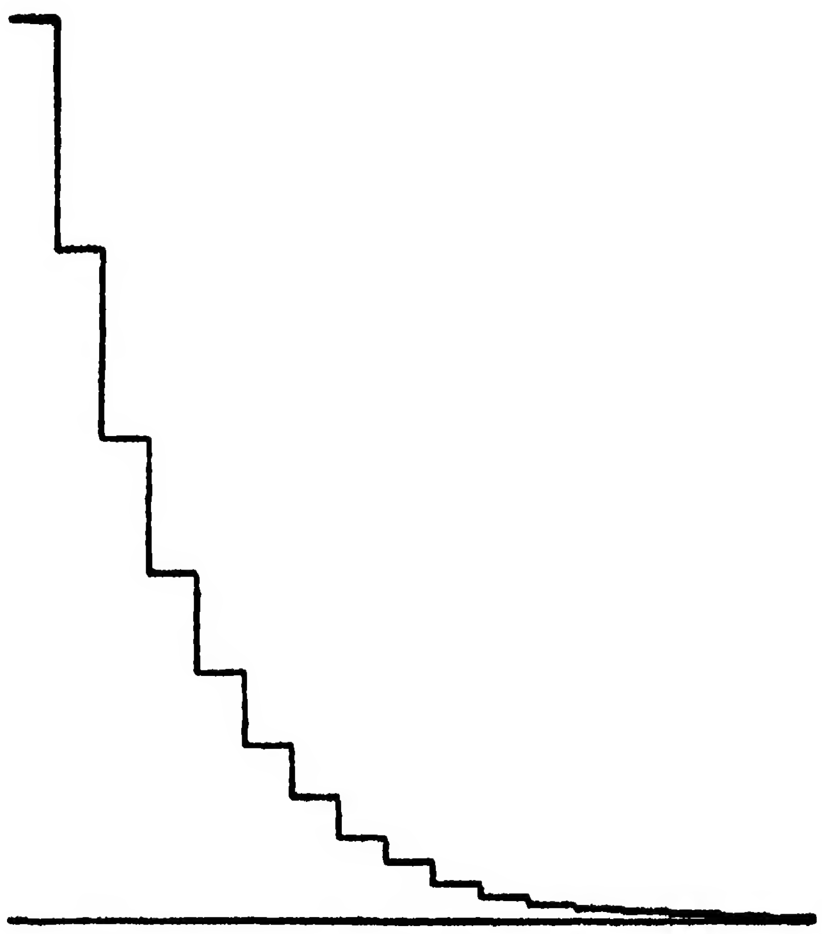


FIG. 1. THE DISTRIBUTION OF PERSONS OF VERY GREAT ABILITY (APPROXIMATELY THE TOP THOUSANDTH) IF VERY GREAT ABILITY IS CAUSED BY A FAIRLY LARGE NUMBER OF FORCES OF APPROXIMATELY EQUAL MAGNITUDE.

ology of the voice overcomes present limitations, or some new practice in human breeding multiplies these rare individuals.

By analogy with what is known of very high abilities that are definable and measurable, such as various athletic abilities, abstract intellect, knowledge of languages and ability to make money in a given profession, it is reasonable to expect that very high abilities are the extreme of a tail of a total surface of frequency, and that this tail has a form like that of Fig. 1, where the high abilities are due to specially favorable concatenations of many independent causes of about equal magnitude, or like those of Fig. 2 or Fig. 3, where the high abilities involve also the action of certain prepotent causes or groups of correlated causes.

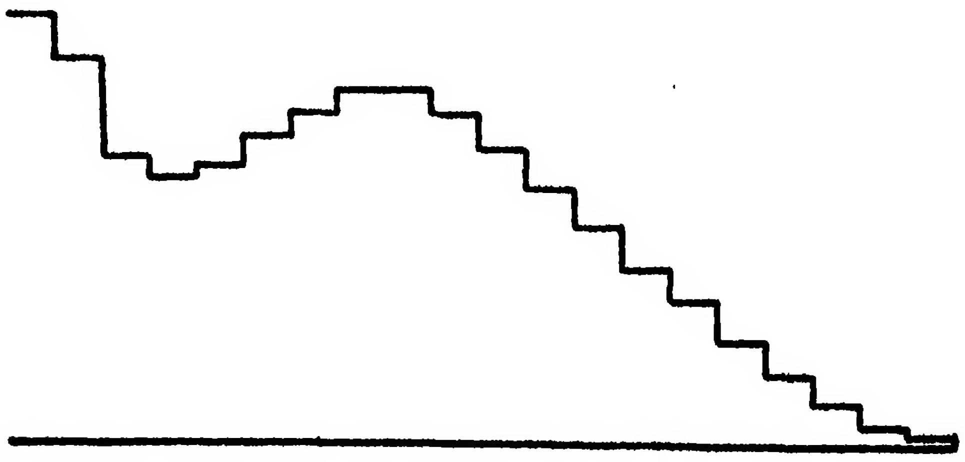


FIG. 2. THE DISTRIBUTION OF PERSONS OF VERY GREAT ABILITY WHEN THERE IS ADDED TO THE FORCES CAUSING THE DISTRIBUTION OF FIG. 1 ONE FORCE OF VERY LARGE MAGNITUDE.

Suppose the high levels of inborn capacity to achieve in a certain line (such as mathematics or law or banking) to be distributed so that the top 6,200 men out of a million will, if they receive no special opportunities, practice or training, be distributed as shown in Fig. 4 at age 50. Suppose that a certain cause or group of causes has the effect of raising the achievement in question from 5 to 16

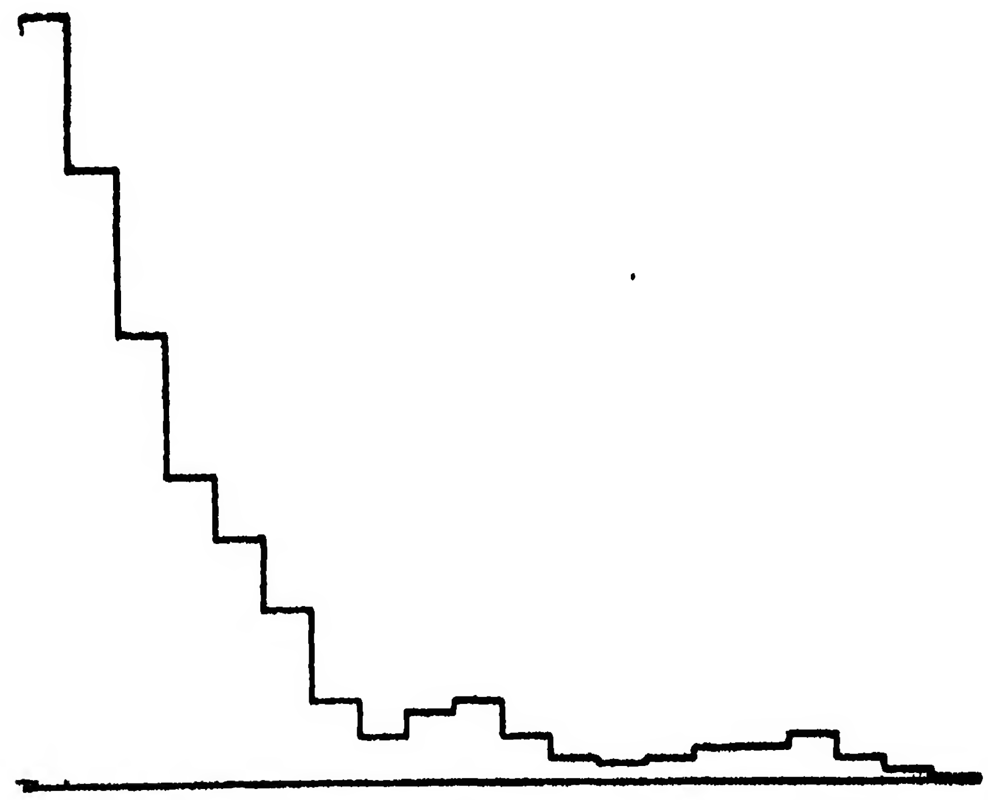


FIG. 3. THE DISTRIBUTION OF PERSONS OF VERY GREAT ABILITY WHEN THERE ARE ADDED TO THE FORCES CAUSING THE DISTRIBUTION OF FIG. 1 TWO FORCES OF FAIRLY LARGE MAGNITUDE.

points with an average effect of 10½. (Such a group might be going to a law school, and being admitted to a good firm.) Suppose that this cause or group of causes acts selectively, upon 10 per cent. of the men who would be at level 125 without it, upon 15 per cent. of the men who would be at level 126 without it, and 20, 25, 30, 35 and 40 per cent. in successive levels from 127 to 131, and thereafter accelerating its selective tendency so as to affect 46, 53, 61, 70 and 80 per cent. at successive levels. Then the distribution will be as in Fig. 5.

Suppose that a cause or group of causes acts in the same selective way, but now increases its potency in relation to inborn capacity from an average of 10½ upon persons of the 125 level, to an average of 11½ upon persons in the 126 level, to an average of 12½ upon persons of the 127 level, and so on up to an average of 21½ at the 136 level. Then the distribution will be as in Fig. 6.

It is often prudent to proceed upon some such assumptions in default of anything better, but so little is known concerning the nature and causation of such

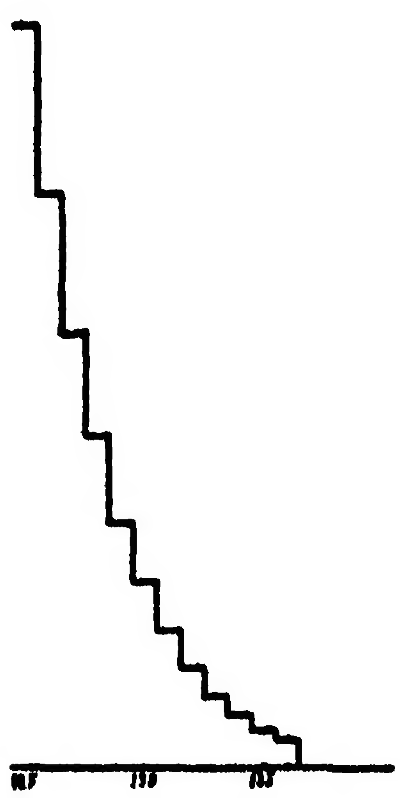


FIG. 4. THE PROBABLE DISTRIBUTION OF THE ABLEST 6,200 MEN IN A MILLION BY INBORN CAPACITY, THE AVERAGE OF THE MILLION BEING 100, AND THE STANDARD DEVIATION BEING 10.

abilities as to trade, manage men, direct a business, sell goods, organize a factory, select investments, foresee changes in fashion, conduct a trial, influence a jury, attract followers, and the like, that such assumptions in such cases are extremely hazardous. How many men in this country would be able to manage the American Federation of Labor as well as it has been managed? To design a dam demonstrably better than Boulder Dam was designed? To direct its construction demonstrably better than it has been directed? To secure 10,000 new subscribers for a certain magazine within

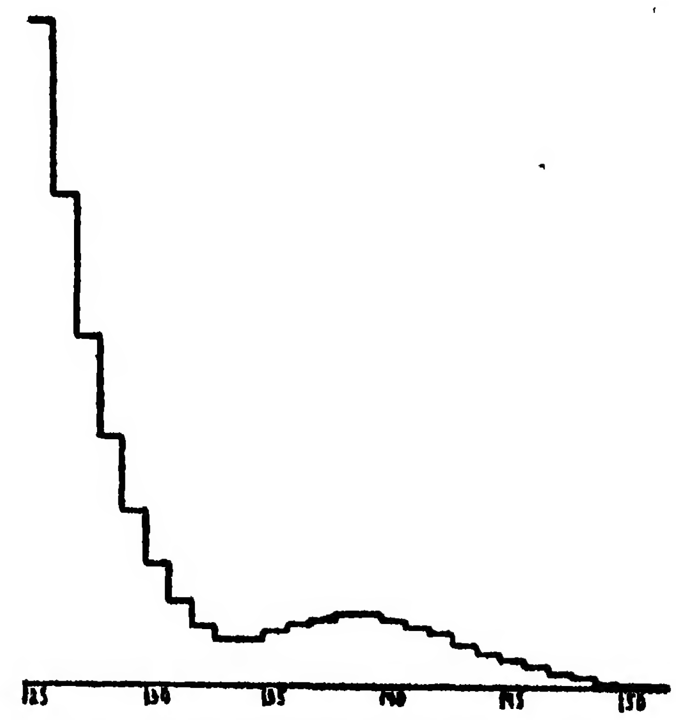


FIG. 5. THE DISTRIBUTION OF THE 6,200 MEN OF FIG. 4 IF THEY ARE SUBJECT TO A FORCE WHICH RAISES A PERSON'S SCORE FROM 5 TO 16 POINTS (10½ POINTS ON THE AVERAGE), AND ACTS UPON 10 PER CENT. OF PERSONS HAVING ABILITY 125, 15 PER CENT. HAVING ABILITY 126, 20 PER CENT. HAVING ABILITY 127, AND UPON 25, 30, 35, 40, 46, 53, 61, 70 AND 80 PER CENT., RESPECTIVELY, OF PERSONS HAVING ABILITIES 128, 129, 130, 131, 132, 133, 134, 135 AND 136.

a year? To displace the present national leader of the Democratic party within two years? To turn ten thousand dollars into ten million within ten years by

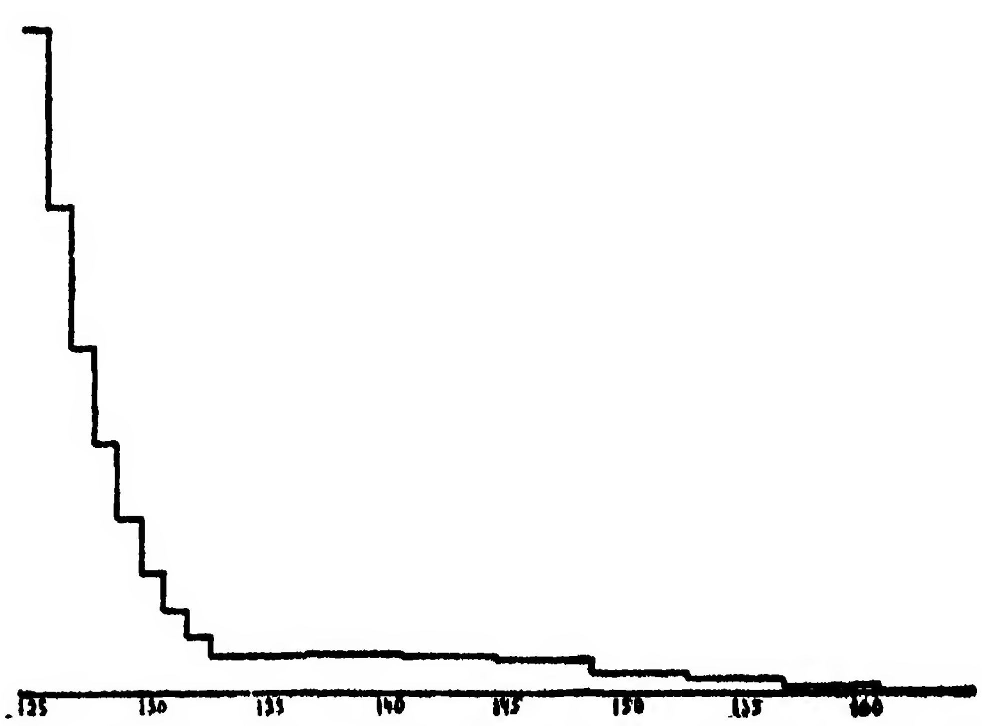


FIG. 6. THE DISTRIBUTION OF THE 6,200 MEN OF FIG. 4 IF THEY ARE SUBJECT TO A FORCE WHICH ACTS UPON 10 PER CENT. OF PERSONS HAVING ABILITY 125, RAISING THEM FROM 5 TO 16 POINTS; UPON 15 PER CENT. OF PERSONS HAVING ABILITY 126, RAISING THEM FROM 6 TO 17 POINTS; UPON 20 PER CENT. OF PERSONS HAVING ABILITY 127, RAISING THEM FROM 7 TO 18 POINTS; AND SO ON UP TO ACTION UPON 80 PER CENT. OF PERSONS HAVING ABILITY 136, RAISING THEM FROM 16 TO 27 POINTS.

trading, and increase this, or at least not lose any of it, during a second ten years? Experts in the various fields may dare to make estimates on the basis of their observations, but general observation and theory can not, as yet, do much more than to put the number somewhere between three and three thousand (or between one in ten thousand adults and one in ten million).[3]

Observation is likely to be misled by two opposite prejudices in estimating the rarity of men able to solve difficult science problems, manage great plants or firms, invest a million dollars a day wisely, or the like. If one thinks of the persons who are by common consent at the top level of ability and then moves down to estimate how many there are who are nearly as good, they seem very scarce. Close seconds to Carnegie or Caruso or Theodore Roosevelt in their respective generations do not readily come to mind. When Locke ran 220 yards in 20.6 seconds he doubtless seemed to many to have no close second.

Such abilities, found perhaps once in five hundred million men and admittedly peerless, are likely to make us belittle those who are really not far below them on the scale in question. In actual fact there were several available who could run 220 yards in only a second more, and there may be many business men and singers not far below the best.

If, on the other hand, one thinks of the symptoms and tests of an ability starting from the average and going to higher and higher levels, one may think that those at each level could, with a little better fortune or a little more effort, equal the achievement of a higher level. From running a small bank to running a large bank, from running one department of a department store to running the whole, from governor to president, the requirements do not seem to increase very greatly, and one may conclude that the next higher level of ability must have nearly as many representatives.

The Discovery of Specially High Abilities

Specially high abilities are presumably no more subject to chance or miracle than eclipses, the weather or anything else in nature. An omniscient observer could presumably predict how high ability any person would display in any line with any specified training. Our present powers of prediction seem slight in comparison with what can be done about eclipses or even about the weather, but are far above zero. A prediction much above chance can be made for any child even before he is born. From age 2 years 0 months or even earlier, certain abilities can be predicted from his sensory, motor and intellectual achievement to date. All predictions are, of course, in terms of probabilities and with a margin of doubt. As a person's development proceeds and records of his achievements accumulate, better and better predictions can be made. When, however, the ability to achieve a certain result, A, is inferred from anything save very similar achievement, there is a rather large probability of error. The specialization of some abilities is so great that abilities so similar as to be called by the same name may not be perfect indicators one of another. Also the person himself may change and so be able to do more or less than he could have done had he stayed the same. But this latter is probably the cause of much less error and doubt than has been supposed popularly. Great shifts like those of Grant are very rare.

Some abilities, as in abstract intellect,

[3] The six abilities taken as illustrations were not chosen with care to have them of even approximately equal height, but simply to be all fairly high, but not impossible of attainment. They probably differ much *inter se*.

music and mathematics, appear early; others, as in the management of men and of money, appear later. The guiding principle is that a capacity will show itself as an ability when situations are met which demand the ability and reward it. So a child with the capacity *can* show abstract intellect as soon as he knows a substantial number of facts and words, or musical ability as soon as he is acquainted with some system of relations of consonance, melody and harmony. If his activities are rewarded (perhaps only by his own enjoyment of them) he *will* show it. A person with the relevant capacity will similarly manage people and money as soon as he can profitably do so, but this will naturally be later. Cornelius Vanderbilt the elder was an active and successful entrepreneur at 12; but school laws, labor laws and social customs would probably prevent him from repeating this if he were born again.

Some sons of well-to-do parents seem to promise little until they graduate from college or professional school, having only a record of good sense, friendships and moderate success in games or other hobbies, and then manifest great ability in business or government. Some of the second-generation executives of Taussig and Jocelyn would doubtless illustrate this, as do the histories of the families which have so largely ruled England. The talents of these men are not such as to be stimulated by lessons or games, or rewarded by extra pocket-money or power over boys, but are called forth by the dignified responsibilities and rewards of adult life.

A scientific personnel manager for the world should, in his arrangements to utilize all specially high capacities, discover and keep track of: (1) children of parents of high achievement, (2) persons who are especially intelligent, (3) persons who are especially sensitive to beauty, (4) persons who are especially creative in the fine arts or useful arts, (5) persons who are especially desirous of excellence and persistent in striving for success, and (6) persons who are especially courageous and independent.

It is probable that a continuous account of the superior abilities that appear at ages 14, 18 and 22, with provision to keep careers open for their talents, would be a useful social investment. Even if nine out of ten of the recipients of such attention and aid achieve only moderately, the investment may yet be profitable provided one in a hundred of those near the top is enabled to do a higher quality of work than he would otherwise have done.

The full argument in support of this conclusion would be long and intricate, but its gist may be realized by considering what the world could afford to pay to develop the ability to cure cancer or make it fashionable for nations to settle their disputes by justice rather than force, ten years sooner than it would otherwise be developed. Even a slight rise in a very high ability is, roughly speaking, priceless. Even a small chance of such a rise is worth a large expenditure. We should not miss the chance by failure to discover the promising candidates early.

Business and industrial enterprises have been supposed to discover very high abilities surely and easily by work "on the job," but this has never been proved. Wise owners and managers of large enterprises are probably as eager to find such persons of high ability as these are to make their abilities known. But the conditions of modern mines, factories, wholesale houses, department stores, banks, railroads, etc., may prevent workers from knowing their own abilities and others from observing or inferring them. Consider the abilities of making financial decisions, improving processes, organizing production, organizing accounts,

managing inferiors, cooperating with equals, selling goods and trading in the case of a man 20 to 25 to-day. Except in the cases of selling and trading, there is some reason to believe that a man of high ability would have it recognized more quickly by becoming secretary, or even simply stenographer, to a high executive, than by working up in one of the regular divisions of the business.

The more the work of an organization is specialized and regularized so that each person's responsibilities are more fully described and prescribed, the less chance there is that persons can show their promise by extraordinary competence in emergencies. We may hope that impartial records of the quality of performance at the regular routine compensate for this lack. We may also hope that the displacement of a hundred thousand general manufacturers and business men by a hundred thousand engineers, accountants, shop-managers, superintendents, sales-managers, credit-men, legal advisers and other specialists not only permits a greater number of high abilities to work, but makes them more discoverable. Theoretically, it should do so. Theoretically, indeed, we should be able to discover high promise for many features of business and manufacturing in men while they are still students in schools of business and engineering.

There are no easy means of estimating how many fine flowers of managerial or entrepreneurial or financial ability waste their sweetness now, or have in times past. It would perhaps be worth while to measure the gains when some hindrance is removed, as when privates in the army are permitted to become commissioned officers by passing certain tests or by the exigencies of war, or as when customary restrictions of certain governmental posts to the nobility are abandoned.

Utilization

The best function of exceptionally high abilities is to perform valuable services which no lesser ability can perform at all, as in scientific discoveries, inventions; masterpieces of painting, music, literature and other fine arts, difficult problems and decisions, and difficult feats in inspiring, persuading, reconciling and otherwise managing individuals and groups.

In modern civilization there is always work of this sort to be done, so that very high abilities should never be unemployed, save for recreation. They should never do anything else, save as a luxury or medicine. From the moment that a man or woman has demonstrated his possession of such ability, society should, in its own interest, arrange that he does for it what only he and his kind can do.[3] If by a miracle some possible Newton or Dante could shovel as much sand per hour as ten thousand men, so that he could command four thousand dollars an hour as shoveler of sand all over the globe, society should, if possible, persuade him not to take that contract.[4]

If the n difficult jobs to be done can be distributed among the N men of high ability so that each does what nobody else even among them can do, or what he can do better than anybody else, there is an obvious arrangement for maximal utilization. But if some individual can do two or more better than anybody else, the matter is not quite so simple; and if the jobs vary in importance and some of the individuals surpass some of the others in

[3] These statements hold true even when there is not surety that he can do so and so, but only a certain probability higher than that for anybody else and enormously higher than the probabilities for 999 men out of a thousand.

[4] As the world is, the possible Newton or Dante would be wise to exercise his shovel magic for a few hours, so as to live thereafter free from financial worries!

several of them, it may be fairly complex. A solution giving maximal utilization will not then be reached if those in authority in respect of each job try to get for that job the individual who will do it best. But it can be reached if all jobs, importances, individuals and abilities are considered together. Table I shows the maximal utilization of ten men for twenty jobs of specified importance which none but they can do. For convenience, it is assumed that each job would require the same time as any of the others.

TABLE I

MAXIMAL UTILIZATION OF 10 PERSONS (A, B, C, D, ETC.) DOING ONE JOB EACH OF 20 JOBS. A y INDICATES THAT THE PERSON IN QUESTION CAN DO THE JOB IN QUESTION

Job	Importance	Person Assigned	Persons and Their Abilities									
			A	B	C	D	E	F	G	H	I	J
1	10			y	y		y		y	y		
2	10		y	y	y	y	y	y	y			y
3	11		y	y		y	y		y		y	y
4	12		y		y	y					y	
5	14			y			y					y
6	15		y		y	y			y		y	
7	15			y			y		y	y		y
8	16	I	y			y					y	y
9	16		y			y	y			y		
10	18				y			y	y			
11	18	C or F			y			y	y			
12	20	H	y			y		y		y		y
13	20	F or C			y			y	y			
14	20	G		y			y		y			y
15	20	D	y		y	y						
16	21	E		y			y					
17	22			y								
18	22	J	y				y					y
19	24	B		y								y
20	25	A	y									

The assignment or direction or attraction of high abilities to one job rather than another may be left to the individuals singly, or to a group of them, or to some body (such as the French Academy, the British Royal Society, the American Academy of Arts and Sciences or the American National Academy of Sciences) supposed to be competent to organize and direct the work of men of genius, or to some branch of the government, or to whatever universities, foundations or business concerns pay for their time.

Psychologically it seems safer to trust as a rule to the individuals themselves plus the guidance they will obtain in the ordinary course of events from their fellow experts. Great writers, painters, musicians, scientists, lawyers, reformers, business men and rulers will doubtless do some selfish, useless and silly things with their talents if paid to do what they please without let or hindrance. Cases can be cited where a great man did better under the pressure of a publisher's contracts, the need to compose music that the market would buy, a grant for the completion of a specified project, a popular demand, the dictates of a superior or other persuasion or coercion from those who were using his abilities, than when he used them freely. But on the whole what great men have done by choice will probably average much higher for the common good than what they have done by pressure from employers, advisers or the public.

Three facts need to be considered in this connection. The first is that there is a positive correlation of about .50 between intelligence and virtue or good will toward men. Consequently, unless we are competent in judging who will work in the interest of mankind, we will do better to trust our fortunes to able persons than to try to pick well-intentioned ones. Second, very able individuals are far likelier to judge correctly *what* work they are likely to succeed at and whether the time is ripe to attack it than anybody else, at least until some man of genius makes it his specialty to study what sorts of abilities are best adapted to what sorts of work. Third, very able persons usually attach much more interest and devotion to self-chosen work. For such a man to work at A when he yearns to work at B is especially wasteful.

Except for reasons of weight, then,

very high abilities may be permitted to choose their own jobs. There is still more reason to permit them to choose their own methods. Only for reasons of great weight should society or any of its agents presume to manage such men and women in their special lines of work.

But the correlations between special abilities and good will, good sense, cooperativeness, balance and other multipliers of a man's value, though almost certainly positive, are far from perfect. In the management of his general life the person of high special ability may profit greatly from direction, persuasion and even coercion *ab extra*. Wise publishers, producers, heads of educational or business institutions, financial and industrial managers, patrons and friends may protect them from distractions, irritations and follies and help to keep them healthy and happy.

The success of entrepreneurs in utilizing the labor of specialists of very high abilities will probably in the next hundred years be more important for their own profits and for the common good than their success in utilizing the rank and file of skilled and unskilled manual and clerical workers. The success of the public in making conditions such that high abilities work in its interest will also presumably become even more important than it has been. Less than ever can we afford to stone the prophets.

Public assistance may safely be given to the education of very able persons and their relief from labor which makes poor use of their abilities by allowances for maintenance. Present practices in the United States are often diametrically wrong, as where a gifted child who at a certain age has advanced far in school is permitted to be sent to work by his parents, while a dull child of the same age must be kept in school.

In the case of a random sampling of about a thousand boys in New York City whose careers were studied from 1922 to 1932, the number of years of schooling received by the top twentieth in intellectual achievement averaged less than half a year more than that for the bottom twentieth.[5]

The public should obviously on all counts demand systems of appointment and promotion by merit in all non-elective government services. This would open one set of careers to individuals of high abilities; and, if physicians, lawyers, workers in the physical, biological and social sciences, engineers and men of affairs who use high abilities for the public good are also given power and freedom in proportion to their demonstrated services, we should have a very useful, though incomplete, insurance against misuse and lack of use of these precious national resources.

The public should also take some pains to learn what sorts of persons and abilities are its real benefactors. It is not entirely fair to ask men of ability to act in the public interest rather than in their own, when the public chooses to be deceived pleasantly rather than told wholesome truths, to be poisoned rather than nourished, and to be debauched rather than ennobled.

Indirect provision for utilization of many sorts of high ability is made fairly efficiently by universities, hospitals, museums, foundations for the advancement of human welfare and other endowed institutions. These provide living expenses and facilities for work either as a gift or in return for moderate amounts of teaching or other service. Indirect

[5] It is a common error to think that society is doing more for the intellectually able than for the dull because the former reach much higher grades. This means chiefly that, with the same gift of schooling in years, the able achieve much more than the dull. In the sample referred to above the top twentieth reached grade 12, while the bottom twentieth reached only grade 8.

provision for utilizing many sorts more or less well is made by business concerns which employ not only men of great ability in managing men, money and machines, but also men of great ability as physicists, chemists, geologists, engineers, architects, economists, statisticians, psychologists, lawyers and others. Just how high the efficiency of the utilization is can not be stated. It probably ranges from a low point where the person is put at work which lower abilities could do as well, but where he at least has adequate livelihood with fairly congenial work, to a point where he is abundantly paid and provided with first-rate opportunities to exercise and improve his abilities. The latter is, of course, likelier to be the case with the abilities to manage men, money and machines, than with the abilities less intimately associated with the management of production and selling so as to meet some demand and thereby pay lenders their interest and shareholders some return on their investment. But the owners, if they interfere at all, will perhaps in the future interfere less with the specialists in a corporation's management than with the high general executives who plan its organization and appoint the top specialists. The high general executives have progressed far from the early days when they treated the specialists as distinctly subordinate in every way and always put upon them the burden of proof, and in general considered that they themselves know more about everything in the business than all those beneath them. They will progress still further and will give freer and freer play to the abilities of others so far as these are exercised for the good of the business. With the vexed question of the degree of correspondence between what is good for the business and what is good for mankind we are not here concerned, beyond noting that if the products produced or services rendered are themselves good for mankind and if there is the amount of control over matters of health, decency, justice and the like now prevalent in civilized countries, the correspondence is much above zero. We may not hope that Adam Smith's "invisible hand" holds it at or near 1.00, but no competent economist would rate it as zero or negative. Moreover, the features of the conduct of the business which are due to the activities of the very able individual specialists are, because of the correlation between ability and good will toward men, more likely than those of foremen, office-managers, salesmen and workers generally to be beneficial, in so far as the benevolence of able persons may be assumed to be beneficial.

There are certain sinister neglects and misuses of high abilities due to selfishness, nepotism, envy, jealousy and other base human passions, and others due to natural and normal self-esteem. A king may use his power fairly well in most respects, but, for fear of losing it, may make little or no use of the great abilities of some of his subordinates. The number of murders of near relatives by kings of old was very large! Dictators, even the most benevolent, seldom take much pains to train able successors. Men have resigned positions of great power and dignity in order to retire to monasteries, or by doctor's orders or to indulge in some hobby, but not often simply to give some abler man a chance to do their work better. Indeed, it is psychologically very hard for one to believe that some of his subordinates are abler than he is, since that conflicts with his long habit of dominance over them, and is also not a pleasant belief to entertain.

As a rule, a man's achievement rises till age forty, holds at a level until age fifty-four, and then falls, though not very rapidly, up to age seventy. But this is not widely known, and a ruler, artist, scientist, professional man or business

man who knew and believed it would still be strongly tempted to think that he was an exception. The drop being gradual and rather slow permits him to do this, and may conceal the fact from his associates until some dramatic comparison with a previous similar demand shows that he does not have the ablity he once had.

Very able men can not then be relied on to do full justice to other very able men in all circumstances. They are, however, more likely to do so than less able or mediocre men. The ablest kings will tolerate abler ministers than less able kings will; and we may expect that the ablest bank presidents will give way to promising juniors oftener and earlier than the petty magnates of small towns.

Very high abilities may be misused by their possessors because of two very important psychological fallacies. The first is the fallacy of overrating one's judgments of all or many sorts because in one's special field they are excellent. The second is the fallacy of assuming that one's might is right on all or many occasions because it has been right in one's special field. A man who day after day has judged correctly ninety-nine times out of a hundred about, say, legal problems, and who gains a moderate knowledge about sociology or politics or art, will feel an unjustifiable confidence in his judgments about the latter unless he reminds himself that he is disqualified from expertness in the latter. A man who has exercised power repeatedly with benefit to all concerned as, say, a bishop or general or company president, will feel an unjustifiable confidence in his exercise of power that comes to him as a college trustee or senator or director of an art museum, unless he deliberately allows for his lesser fitness for the latter parts.

Such misuses are not of very great importance, first, because men of very high abilities usually are too interested in their own specialties to interfere much in other lines; second, because they are intelligent about their limitations, and third because, even if overvalued, their exercise of thought and of power will still be much better than the average, though below that of the expert. Such misuses should, however, be reduced. In particular, men of very high literary or oratorical gifts could well have their statements about philosophy, religion, education, government and reform criticized by experts lest their talents make the worse appear the better; men of great ability to make money could wisely inform themselves concerning the correlations of this with other abilities; a man of high abilities of any sort should abate, outside of his specialty, the peremptoriness and absolutism which is his right within it.

If the leading specialist in treating a certain disease discovers a preventive of it, he may lessen his own income greatly by making the discovery public. Yet, as Professor Cattell has often remarked, the public gives him nothing to offset this. The ablest lawyers make a great financial sacrifice to take posts as judges or as professors in schools of law. Army officers highly competent in engineering and management have attractive chances to leave the service for private employment. And, in general, very high abilities which can be employed for private ends will be sought for these, and the private concern will usually outbid the public. For example, great scholars or scientists will be paid far more for writing text-books than for doing research. The case is different with low abilities, where the public often pays more money and security than private employers would offer.

The attitude of very able persons toward public versus private employment varies, of course, enormously with the person and the nature of the employment,

but certain facts are of wide applicability. Very able persons do consider, more than others, the common good and the good of the future and will make sacrifices for it. They seek, more than others, freedom to do excellent work and especially abominate either political or commercial pressure which forces them to do shoddy work. They demand permanence of tenure in public work not so much to be sure of a livelihood as to be sure of protection against political pressure. They are more sensitive than others and seek freedom to work in their own way and among congenial surroundings.

No community has planned and arranged to discover and utilize all the very high abilities of its members. There may be a large waste because of discouragement or lack of encouragement, especially lack of financial support. The amount of the latter varies from near zero in the case of some prophets, reformers, philosophers, mathematicians, scientists and scholars to a large superfluity in the case of some entertainers, managers, entrepreneurs and traders.

Since great ability has much more than its share of able ancestors, some provision is made by them. In Odin's study of the conditions of nature and nurture of eminent French men of letters, the number who were brought up in chateaux was large. In Taussig and Jocelyn's study of business executives, the parents were often successful business men. The sons of clergymen and teachers have been distinguished for high achievement in science, scholarship and the professions; and their parents probably usually provided encouragement other than financial.

Some provision is still made by individual patrons. Young people who are highly gifted in music or painting do receive such help and probably could oftener if they could not be provided for otherwise. A boy or girl equally promising in science or scholarship would probably not obtain such patronage and would now be regarded as eccentric and lacking in self-respect if he asked for it. After a certain amount of training the able protegée in art or music is left to earn his living and probably can do so without excessive sacrifice, though this is not sure in the case of musical composers.

In general, individual patronage is very rare, but the universities and foundations supply it in the form of scholarships and fellowships, a few of which are adequate for complete support. Maintenance allowances during the period of secondary education have been proposed in various places and are being seriously considered by public authorities in France. The provision of financial aid during training is very uneven and more benevolent than efficient. For example, the aid available for intending clergymen is far richer than that for intending physicians, the latter being indeed almost nil. The theory is rather to reward religious devotion and palliate future poverty than to provide for public welfare.

If he has somehow obtained training, the highly gifted engineer, lawyer, physician or clergyman can usually make a living at more or less instructive work. The highly gifted scientist or scholar can, if not too eccentric, make a living by teaching or expert service. Poets and other literary men can, thanks to Pultizer prizes and Guggenheim fellowships, receive financial rewards for the work they most wish to do, or can become entertainers, as so many of the greatest of their kind have done.

Prizes such as those of the Nobel fund have the merit of giving individuals of great ability wherewithal to provide essentials and make old age secure and also of informing the world who some of its great benefactors are. The same is true of a system of national pensions such as those of the British civil list, especially

if they are large enough to be impressive to the public. Such public honors by way of financial support are not popular, however, and even in the enormous increase of public expenditures of the last generation, almost nothing has been spent directly to reward great public services.

It therefore seems politic to work rather for the support of universities, museums, hospitals, social settlements, institutes for science and scholarship, orchestras, and the like which are for the public good in and of themselves, and which will provide, as one by-product, dignified and congenial ways of earning a living for those high abilities which are not paid for by the general demand for business and professional services.

Nobody knows how many of the very high possibilities in the genes of the ten million persons born in this country from 1870 on who survived to age 50 or later, have been realized. To be definite we may consider the fate of the top thousand in the ten million, that is, the top one per ten thousand. If some omniscient guardian angel could have recorded the possibilities of each of the ten million at conception, at birth, at age 5, at age 10, at age 15, at age 20, at age 25, at age 30, and so on, nobody knows how fully the possibilities existing for any thousand at any age were realized in their lives thereafter. But not the most ardent believer in the relative importance of the genes and their tendency to find or create the environment they need, would claim that the possibilities were 100 per cent. realized.

The reader may well make the best guess he can and act upon it when he has a chance as, voter, donor, adviser, or the like, to further the utilization of the nation's most precious asset. The writer's guess would be that our eventual utilization of possibilities existing at age 15 varies from as low as .30 in the case of capacity to govern well to as high as .80 in the case of managerial and entrepreneurial capacities, and to .90 or .95 for trading ability; is about .60 in the case of the fine arts, science and scholarship; and is about .70 in engineering, invention, law, medicine and education. These percentages concern the numbers of persons who are doing the sort of work which they should be doing in the world's interest. The percentages of utilization, including also putting their abilities to work as early as is best and keeping them at work under the best conditions, would be lower.

Probably nine out of ten psychologists and sociologists would consider my estimates as far too high.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

THE EFFECT OF SCIENCE UPON MAN

It can be argued that the only truly direct effect science has had upon man is the application of medical and health knowledge that has lengthened his life span and reduced the birth rate. Autos, radios and all the impacts of physical science upon man's environment? Merely indirect and secondary, although admittedly important.

An intellectually exciting idea put forth by Frederick Osborn, population authority, in some of his thinking on eugenics is this: "Both births and deaths are more subject to human decisions and to a man-made environment than ever in the past. Man is given a new responsibility he did not expect and which he is as yet wholly unprepared to discharge."

The objectives of the newer eugenics are not particularly radical and are not centered upon sterilization or such techniques. They are concerned with making the best of what we have through education. This applies to determining who shall be born into the world as well as what happens to them afterwards. Most emphatically eugenics to-day does not desire to make a selection between social, economic or racial groups.

In the last few years science has amply proved, in Mr. Osborn's opinion, that whether or not there are differences between such groups with respect to the average capacities of the individuals which compose the group, such differences in average capacity are relatively small. On the other hand, the differences between individuals in the same group are known to be very large.

Eugenics thus demands a selection between individuals. It asks simply for a gradual increase in births among those individuals who are above the average of their group in socially valuable qualities. It wants a gradual decrease in births among those below the average of their group in socially valuable qualities. On the average, it is found that those parents who provide the best home training for their children are also those with the best genetic stock. This is a rather happy philosophy for planning mankind's future.

PRODUCTION OF HEAVIER NITROGEN AND SULFUR ATOMS

When a factory starts to produce a new kind of product, that's news. When the product consists of a kind of matter that has never been available before, that should be even bigger news.

At Columbia University in New York City, Dr. Harold C. Urey is engaged in manufacturing for scientific purposes relatively pure isotopes, kinds of atoms that a few years ago science did not realize existed.

Dr. Urey is a winner of the Nobel prize in chemistry for his discovery of what is now called deuterium, the kind of hydrogen that is twice as heavy as the common kind. Deuterium (D) is now available in the form of heavy water and otherwise in extreme purity and in sufficient quantity. You can buy it for about a dollar a gram (1/30 of an ounce), which is cheap enough. Scientists use deuterium to tag the way compounds behave during chemical reaction. They are finding that the heavy kind of hydrogen

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

does modify the compounds in which it takes the place of common, light-weight hydrogen, although it is not deadly as some feared—or hoped—when it was first discovered.

Now Dr. Urey is separating out two other isotopes, nitrogen (N) of mass 15 and sulfur (S) of mass 34, which is a much more difficult task. He uses a sort of giant still that is 150 feet tall, or rather would be if a very trick, non-valve pump for gases and liquids did not allow him to put the whole apparatus on one floor. The heavier atoms of nitrogen 15 (the common nitrogen is mass 14) and of sulfur 34 (the common sulfur is mass 32) tend to separate out at the bottom. He is treating raw materials by the ton.

Just now there are only scientific uses, but you never can tell just when some industrial use will be found. Costs? Per gram-atom, D is $10 commercial; N 15 is $180 and S 34 is $40, for materials used.

POLARIZED LIGHT IN INDUSTRY

A new industrial revolution is in the making and it will be created out of light. Practical applications on a large scale are foreseen now that man can create and control the kind of light that vibrates in one plane only. This kind of light is called "polarized light."

What the vacuum tube, familiar in our radios, did for applied electricity, a cheap and convenient means of polarizing light promises to do for optics.

For many years the polarization of light has been understood and used in a limited way. Expensive Nicol prisms, made from suitable crystals of Iceland spar, have long been used in microscopes and other optical instruments. The effects of polarized light have long been demonstrated in classroom physics experiments.

It is startling to have light blotted out by a mere twist of a disc that had been perfectly transparent. This happens when the prisms are "crossed" or arranged so that their "one-way streets for polarized light" block each other.

The new development in polarized light is the commercial production of large sheets of polarizing material, called Polaroid. Millions of small, needle-shaped crystals of the chemical, sulfate of iodo-quinine, are laid down in a film, which may be a yard or more wide and continuous in length. This synthetic sheet polarizes perfectly. Some of the practical applications are:

A desk lamp that eliminates glare from papers on the desk.

Sunglasses that rub out sunlight reflections on pavements, sea, ice and snow.

Elimination of auto headlight glare by use of 45 degree polarizing screens on headlights and windshields of all cars.

Photographic filters for surface reflection elimination.

Colored illumination and advertising displays.

And the most promising of all, perhaps, stereoscopic or three-dimensional motion pictures in color.

THE STUDY OF VOLCANIC GASES

Professor Stanley S. Ballard, of the University of Hawaii, who is also research associate in geophysics in Hawaii National Park, tells in a new publication of methods for getting information about what goes on inside a volcano by capturing and studying the gases that come out of it.

The hottest parts of the volcano's breath, the gases that are actually flaming as they emerge, are of course uncapturable. Nevertheless, that does not mean that they can not be examined. By turning the slitted telescope of a spectrograph on them as they glow, it is possible to split their light up into its component wave-lengths and to get a record of these as lines on a photographic film for later measurement and interpretation.

Preliminary work of this kind has been done, but with instruments too small to

give really valuable results. Professor Ballard hopes to get a piece of scientific artillery of sufficient caliber to make a really telling assault upon the volcano's fiery citadel.

But actual samples of the gases themselves, that issue from fissures on the volcano's flanks and cracks in its crater floor, can be taken in suitable glass vessels, carried off to the laboratory, and put through the ordinary course of chemical analysis.

It is proverbial that "He who sups with the Devil must bring a long spoon." Volcanologists keep their distance by providing their sampling flasks with very long necks, and sometimes mounting them on poles as well. They poke the end of such a long-necked flask into the fuming volcanic vent. The flask has previously had its air pumped out; so when the seal is broken the gases rush into the vacuum. Then a stopcock is turned and they are trapped.

VITAMIN ALPHABET SHOWS SIGNS OF SHRINKING

From a vitamin expert and professor at Yale University School of Medicine, Dr. George R. Cowgill, comes the news that many claims for the existence of new vitamins have been shown to be untenable. What appeared to be new vitamins were just extra quantities of some of the old familiar ones.

Dr. Cowgill cited the case of the vitamin B complex as an example. Originally there was just one vitamin B, found in rice polishings, whole grains and cereals and yeast. Lack of this vitamin caused the severe nerve disorder, beriberi, in man and a similar condition, polyneuritis, in fowl.

After the original discovery, scientists continued to study this vitamin and the more they studied the longer grew the list of B vitamins. Finally there were vitamins B_1, B_2 (also called vitamin G by American scientists), B_3, B_4, B_5, B_6, and two more substances called filtrate factors. All of them were considered necessary for normal growth and each one was believed to have in addition certain special effects, or rather lack of each one was believed to result in separate nutritional disorders. It was all very confusing and a special committee of scientists had to be set up to straighten out the matter of names alone.

Now, however, things are growing simpler. The chemical structure of vitamin B_1 is known and the vitamin is called either thiamin, its chemical name, or simply vitamin B. It is the beriberi preventive. B_2 turns out to be riboflavin and instead of being a pellagra preventive is a preventive, Dr. Cowgill states, of a degeneration of the spinal cord. The special effects of B_3 and B_4 are now known to be due, according to Dr. Cowgill, to a larger supply of B_1. The effect of B_5, noted in pigeons, has been explained on other grounds.

THE FORMATION OF VENTILATION SPACES IN ROOTS

Cells dying that other cells may live furnish the explanation of the air spaces found in the roots of plants like water-lilies, cattails and other forms that grow in unaerated soil and yet must have oxygen to sustain life. Air from above passes down through these spaces, and carbon dioxide waste presumably goes out through the same channels.

But the death of cells in such root tissues is not a nobly self-sacrificing piece of altruism. They just can't help it. They happen to be the ones that suffocate first when the oxygen is cut off, and their breakdown leaves air passages open, so that the rest don't need to die. And thus the roots, and the whole plant, are enabled to survive.

The story of the formation of these ventilation shafts through living root tissues was told at the recent meeting of the Royal Society of Canada by Dr. D. C. McPherson, of the University of Toronto.

Dr. McPherson used in his experiments only plants that do not normally

need or have air passages through their roots, principally corn. When corn plants were grown with their roots deprived of oxygen, groups of cells died and degenerated, leaving spaces open, through which the remaining tissues obtained the necessary air. Parallel plantings with plenty of oxygen in the soil did not form air passages.

Some other plants, like peas and beans, proved unable to form air passages even though oxygen starvation killed cells in their roots. This was because a hard chemical compound, calcium pectate, formed in the cell walls, preventing them from breaking down when they died. Corn cell walls, made of softer stuff, can and do disintegrate.

Dr. McPherson considers that water-dwelling plants that normally have air spaces originally had none, but developed them in response to physiological need as they came to grow in unaerated soils. But now they are so accustomed to having these ventilation passages that if they are forcibly prevented from forming them they will die.

SCORPION STINGS AND SPIDER BITES

Scorpions and spiders come in for a drastic debunking at the hands of Professor W. J. Baerg, University of Arkansas entomologist. For all their dreadful reputation, there are no really deadly scorpions in the United States, and the only dangerously poisonous spider is the already notorious Black Widow. Scorpion stings, declared Professor Baerg, are no worse than those of wasps, and tarantula bites are about on a level with the jab of a dull pin.

Scorpions are ready to sting on slight provocation. The effect is immediately painful, but passes in about half an hour. Tarantulas are not quite so aggressive, though if you really want one to bite you she will usually do so upon sufficient provocation. But some tarantulas won't even do that. Professor Baerg mentions appreciatively a curly-haired Honduran tarantula that has never yet bitten him, despite all kinds of coaxing.

The Arkansas biologist is willing to venture one categorical statement with regard to tarantulas: "No tarantula has a poison that produces dangerous general symptoms in man. A few tarantulas are poisonous to man but the effect is local."

Outside the United States, and confined to Mexico so far as now known, there are a very few species of scorpion whose sting may result in death. One of them, ironically enough, prefers to live in the neighborhood of human habitations. Since the development in Mexico of a serum treatment for scorpion sting, the number of cases ending fatally has been much reduced.

Even the dreaded Black Widow, although admittedly able to cause extreme pain and violent discomfort, rarely kills, says Professor Baerg. "The patient always recovers (excepting possibly infants) unless hampered by serious complications such as a very weak heart, or a syphilitic condition."

Professor Baerg's conclusions are stated in detail in the June issue of *Natural History*, publication of the American Museum of Natural History.

THE TONE OF OLD VIOLINS

After two centuries, it now appears that scientific research is disclosing the secrets behind the tonal beauty which has rightly made famous the instruments of Stradivarius, Amati and other old Italian violin makers. Of more practical importance to all lovers of music, the researches of modern science are showing what must be done to make instruments comparable in tonal qualities with those of the old masters.

Although many men, including some of the best scientists in the world, have tackled this problem, it has been only recently that progress has been made. The ability to amplify sound waves electrically and to present a visual picture of the wave characteristics on an oscillo-

graph are the two key research wedges which are prying apart the long-lost secrets of an old violin's tones.

Once the wave form of a tone from a violin is obtained it is possible, by harmonic analysis, to discover the distribution of the sound energies among the fundamental tones and overtones. It is this distribution which sets off a Stradivarius from just another "fiddle."

Such overtones are caused by the multiple vibration of the bowed string. The existence of these extra vibrations can be shown by placing several little "saddles" of paper over the string and bowing it. Where the vibration is intense the saddles jump off. Where vibration nodes exist the saddles stay in place.

The Danish scientist Poul Jarnak, working in the United States through funds of the H. C. Oersteds Foundation, Copenhagen, has not only made studies on the tones of violins but has developed experimental instruments which compare very closely in tone with expensive 17th century Italian violins. This comparison is made not only by the oscillograph records but also by the ears of trained musicians, says Mr. Jarnak in a report published in the *Journal* of the Franklin Institute.

SUGARS IN NUTRITION AND INDUSTRY

All that is sugar is not sweet. Some sugars are bitter, others are poisonous. Besides the kind of sweet crystals in your sugar bowl, there are literally hundreds of substances chemists know as sugars. Some, like the common sugar, are cheap. Others are very expensive.

Nor is purity, in the case of sugars, a matter of cost. Sucrose obtained from the sugar cane or sugar beet is highly purified and it is one of the cheapest substances in the grocery store. An industrial bulletin from A. D. Little, Inc., points out that a crude sucrose, obtained from maple trees is relatively expensive and furnishes a classic example of how value may depend almost entirely upon the presence of impurities, which in this case impart the distinctive maple flavor that gives this sugar its favored place in commerce.

Dextrose and lactose are two other extensively used food sugars. Also known as glucose, dextrose is produced from the starch of corn and is sold as the major part (50 per cent.) of corn syrup and as dry white crystalline material. These crystals at about 4 cents per pound are perhaps the cheapest organic material produced. Lactose is milk sugar. Babies can digest it at birth. Heat caramelizes it to produce that attractive golden-brown color of biscuits, bread and pie crust.

Sugars are one of the important raw materials for chemical manufacture. Vast quantities of molasses are the starting point for producing alcohol, citric acid, yeast and other products. Dextrose is fermented on a large scale to produce chemicals and is reduced by electrolytic means to give rise to the sugar alcohols, mannitol and sorbitol, which are new to commerce.

One of the so-called rare sugars, trehalose or mycose, found in fungi and in the manna of Persia, is possibly the most chemically stable of all sugars, resisting the combined action of alkalies and oxidizing agents.

IMPORTANCE OF FATS IN DIET

Most persons do not need to be told to eat fat. They like the flavor and they have probably learned from experience that a meal with fat in it has more "staying" power than a meal without. So, more or less automatically, butter is spread on bread, oil is put in salad dressings, cream goes in coffee and bacon is eaten with eggs.

The scientific reasons for eating fat and some of the newer knowledge about fat are less well-known but interesting. For example, the reason why you feel hungry sooner after eating a meal with little fat than after a meal with lots of fat is because fat leaves the stomach more slowly

than protein foods or starches and sugars. Moreover, fat eaten with these other kinds of foods—bread and butter or bacon and eggs—retards the digestion of the other food substances.

Besides adding to the feeling of satisfaction after a meal, fat is the best of all foods for giving energy. Weight for weight, the fats give more energy than either proteins, such as meat, or carbohydrates, such as bread, cereal and potatoes. The reason for this is that fats contain a higher proportion of carbon and hydrogen, they are relatively drier than the carbohydrates and proteins as ordinarily eaten, and fats are more completely digestible than the other classes of foods so that there is almost no waste.

You can get along with very little fat. An experiment has been reported in which a man lived for six months on a diet containing only two grams of fat per day. Two grams is equivalent to about seven hundredths of an ounce—a mighty small speck of butter. Surprisingly, this man felt no fatigue. The rest of his diet, however, was very carefully planned. An ordinary fat-lacking diet, such as was eaten in European countries during the World War, results in premature hunger, lowered energy and reduced capacity to work.

The average adult should eat about one third of his daily calories as fat. Margarines or processed vegetable fats give better value for the money than butter, but ordinarily lack the vitamins A and D which butter supplies.

AUSTRALIAN TRIBES

America has its Indian problems. Australia is having trouble with its aborigines. Australians have not, of course, left the black men entirely to shift for themselves. They have studied the natives as interesting specimens. They have provided aboriginal reserves. They have offered medical treatment. Recently they appointed an anthropologist to be Protector of Aborigines.

But still Australia's tribes are reported to be "dying on their feet."

Somehow, these Stone Age people evade the scraps of civilization handed to them. They prefer to roam where they please. Sick as thousands are, they are wary of white doctors. They continue to die, rapidly.

Defenders of the natives protest against unfairness on some reservations, where white men encroach, taking land for their industries and their own uses.

Sir James Barrett, of Australia, in a letter to *Nature*, points out that there were about 300,000 aborigines in Australia when Europeans took charge in 1788. Now, there are none in Tasmania, about 50 in Victoria, a few in New South Wales. Tropical Australia still has about 60,000, and there are some 22,000 half-castes.

Sir James suggests that half-castes or aborigines be trained in medicine, so that they may give medical care to their own people.

Anthropologists have suggested that the natives be put on land where outsiders are admitted only on duty, and that the natives be left in peace to live in their own fashion.

The natives have a suggestion. Recently, they petitioned King George, asking representation in the Federal Parliament. This, they believe, would help them to get justice in the matter of lands and legal rights. They even believe it would save their people from extinction.

Representation seems to be one feature of civilization these natives have decided they need.

BIBLICAL PLAGUES AND EGYPT'S HEALTH

The Biblical plagues still afflict the land of Egypt. Far from being a never-repeated reign of terror, the plagues with which Moses frightened a Pharaoh into releasing the Israelites were fearful because of their familiarity. And they

still recur in more or less serious form, like our own epidemics and other trials.

The sequence of health hazards which the Nile brings each year was deplored recently before the World Federation of Education Associations by a physician of the government health service in Cairo, Dr. Isabel Garvice.

Pointing out the Biblical antiquity of these conditions, Dr. Garvice said that every August, then and now, the rising Nile turns blood-red from its load of heavy mud.

To drink this water is to invite sickness and death. Yet the Egyptian peasant is convinced that drinking well water would turn his hair gray and make him old before his time. Rather than risk such calamities, he clings to his year-round habit of drinking from river or canal, and the blood-red water brings the plague of boils. The children, says Dr. Garvice, often have ten to twenty boils on face and body.

As the flood waters lessen, come the plagues of frogs, flies, and death to the babies.

Even the three days of darkness which enveloped the earth in the Bible siege of plagues, is still experienced. The darkness takes the form of sandstorms, which are still terrible in upper Egypt and still last three days.

"All these things," said Dr. Garvice, "are put down to the will of God and accepted with resignation by the peasant."

But the Egyptian government is determined to cope with its plagues. Children, under compulsory schooling, are being taught health habits and given medical attention. Rural villages are shown hygiene films. Medical centers are established. The conquest of the plagues is advancing—slowly.

INSECT PESTS IN JUNE

If we mortals really could control the weather, as sometimes we wish we could, we would be up against a very difficult problem in June. What this country needs is two kinds of June: a cool wet month, with driving rains, from Illinois west to central Kansas, and a hot, dry one from Indiana east to New England.

This is because of the crop pest situation. In the corn belt the great threats are grasshoppers and chinch bugs. These thrive in hot, dry weather but are drowned, beaten into the earth, and exposed to their natural enemies by cold rains in late spring.

From Michigan and central Indiana eastward, the outstanding enemy is the European corn borer. The flying adults move from field to field most easily in cool, moist weather, so that farmers in its occupied territory have cause to pray for less rain rather than more. A really good dry spell some time in June would prevent a good deal of the damage that otherwise will befall corn and the many other crops the borer infests.

There is a certain amount of overlap in the ranges of chinch bugs and corn borers, so that in that area there is bound to be some trouble, no matter what the weather.

Probably, if a choice had to be made, it would be better to take the weather that would discourage the borer, and to tell grasshopper and chinch bug to come on, and to come a-fightin'. For entomologists have worked out control methods for the two latter pests which are fairly effective, even if expensive, while for the borer no real control has yet been discovered.

The best that can be done to fight corn borer is to make a thorough cleanup of all stubble in the fields it infests, plowing it under clean and deep and burning what can't be plowed under. The resting larvae lurk in such trash, and if any of it is left undestroyed, presently there will be enough of the winged adults to reinfest the whole neighborhood.

TREES THAT UNITE WITH EACH OTHER

By Dr. HENRY I. BALDWIN

NEW HAMPSHIRE FORESTRY AND RECREATION DEPARTMENT

TREES are naturally gregarious plants, but they are usually distinct individuals like animals. Occasionally some groups like mangroves in the tropical coastal swamps, and our speckled alders (not usually classed as a tree) grow from a common root and are hopelessly intermingled. Yet even in sprout forests, stems which branch below breast height are commonly considered separate trees. Many stems springing from a common root or base is a common form throughout the plant world. Single stems or branches which later unite are, however, unusual and deserve mention.

Natural grafting, as this odd joining of stems or branches is called, by analogy with the artificial horticultural practice of grafting twigs or scions of one variety on stock of another, is more common in some regions, and among some species than others. It is also much more common underground between roots than above ground. Tropical trees, shrubs and vines are especially prone to join their members. The late Dr. John K. Small has described grafts in the pond cypress (*Taxodium ascendens*) and in several sub-tropical hardwoods.[1] The tropical strangling fig forms unions with the slightest contact.

In temperate regions trees with very active cambium or growing layers close under the bark tend to graft more readily than other kinds. Spruce, for instance, almost never joins, but hemlock does often. Aggressive species graft more commonly. In second growth forests in the Northeast white pine, the maples, birches, ash, basswood and beech not infrequently become fastened together and occasionally the wood fibers become joined and the sap stream passes from one member to another. Where the bark is occluded and the branches or trunks are merely stuck together there is really no union. These may be termed false grafts. In no case observed by the writer has an actual union of the living wood elements occurred between different species of trees, but it may take place. "False grafts" are especially common in second growth hardwoods where sprouts crowd one another for space.

Stem grafts only are illustrated here, but root grafts are almost omnipresent. The competition for growing space above ground in the forest is as nothing compared to the maze of roots beneath. The soil is a far more unyielding medium than air, and when roots become interlaced and then grow in diameter there is frequently no room for expansion except into one another. Arborists speak of root-girdling. LaRue[2] examined stump fences in Michigan and estimated that at least 3,000 white pine stumps in a distance of 10 miles showed root grafts. Some individual stumps showed as many as 120 separate grafts. The writer has made similar observations in northern New York and New England. Hemlock also forms root grafts and where beech roots are exposed they will be found cemented together into a regular network. This condition was demonstrated strikingly during some tree injection experiments carried on by the writer in

[1] J. K. Small, *Jour. N. Y. Bot. Garden*, 33: 213–219, 1932.

[2] C. D. LaRue, *Am. Jour. Bot.*, 21: 121–[illegible], 1934.

UPPER LEFT. DOUBLE GRAFT BETWEEN TWO PINE STEMS, FOX RESEARCH FOREST, HILLSBORO, N. H. UPPER RIGHT. GRAFT BETWEEN TWO PINES, FOX RESEARCH FOREST, HILLSBORO, N. H. THE DEAD TOP OF THE GRAFTED PINE PERSISTS. LOWER LEFT. TRUE GRAFT BETWEEN TWO YELLOW BIRCHES, WITH FALSE GRAFT ON SUGAR MAPLE. MT. SUNAPEE, N. H. LOWER RIGHT. GRAFT IN WHITE ASH. CONTOOCOOK STATE FOREST, HOPKINTON, N. H.

LEFT. YELLOW BIRCH AND WHITE PINE GROWING IN INTIMATE CONTACT ON HARVARD FOREST. A FALSE GRAFT. TREES CUT FALL 1934. PETERSHAM, MASS. UPPER RIGHT. TRUE GRAFT BETWEEN TWO WHITE PINE STEMS. FOX RESEARCH FOREST, HILLSBORO, N. H. BELOW LEFT. TRUE GRAFT IN BEECH. EDGEWOOD PARK. WHALLEY AVE., NEW HAVEN, CONN. BELOW RIGHT. GRAFT IN BLACK BIRCH. MALTBY DIV. ELI WHITNEY FOREST, NEW HAVEN, CONN.

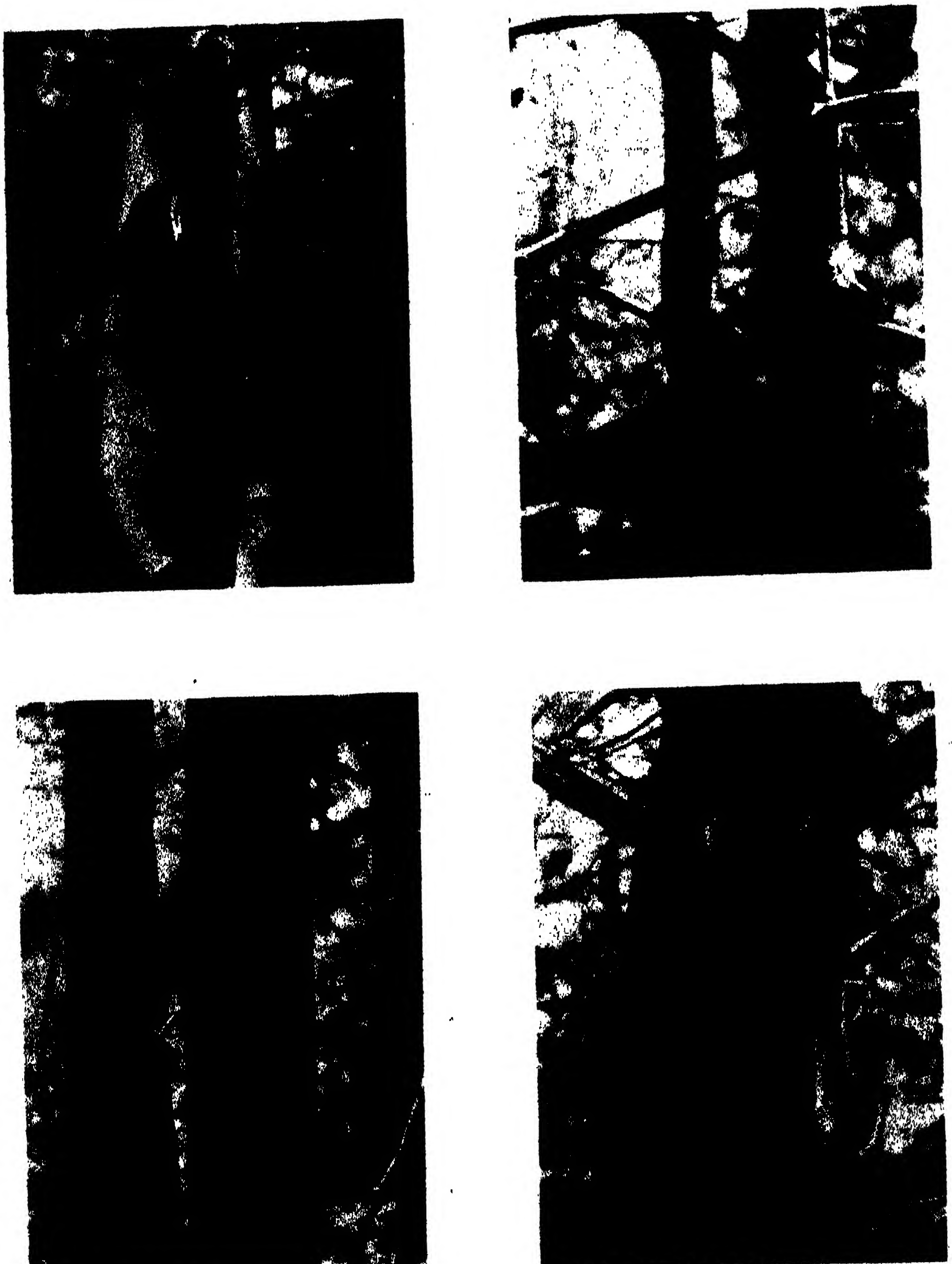
1925. When a red dye was introduced into one beech all others for a radius of 50 feet were found to be dyed. A similar experience is reported in dutch elm disease control work. Infection in one tree in Indianapolis was found to have spread to six others with whose vascular system it was joined by root grafts. Callousing and continued growth of stumps after the trees have been cut is another common evidence of root-grafting. Page[3] has studied these in white pine near Hanover, N. H., and found that stumps continued to grow for several years following cutting from food supplied by nearby trees. Büsgen and Münch[4] also report root grafts in spruce, silver fir, douglas fir, larch and rarely in scotch pine, causing stumps to live for decades. LaRue failed to find root grafts in tamarack (American larch). The forester can not always eliminate competition below ground by thinning the aerial parts of trees, it would appear.

A good illustration is furnished by girdling experiments. In 1924 hardwoods in Northwestern Maine were girdled in order to release spruce suppressed by them. Some trees died the first year, others in 3 or 4 years, but some small beeches were only slightly impaired in vigor by this ringing and were alive 10 years later. Now beeches are extremely sensitive to changes in moisture supply, and hence easy to kill by ringing. Examination showed numerous small saplings which were either root suckers or were grafted to the roots of the girdled trees. The nature of the cambium probably determines what species form root grafts. LaRue concluded that abrasion or friction of the bark due to rocking of the trees was not necessary to cause the cambium layers to unite, but that the pres-

[3] F. S. Page, *Jour. Forestry*, 25: 687–690, 1927.

[4] M. Büsgen and E. Münch, "Structure and Life of Forest Trees." English translation by Thomson. 365. N. Y., 1931.

LEFT. BASSWOOD TREES IN CLOSE CONTACT. A SITUATION WHICH SOMETIMES GIVES RISE TO GRAFTS. RIGHT. TRUE GRAFT BETWEEN PINE STEMS.



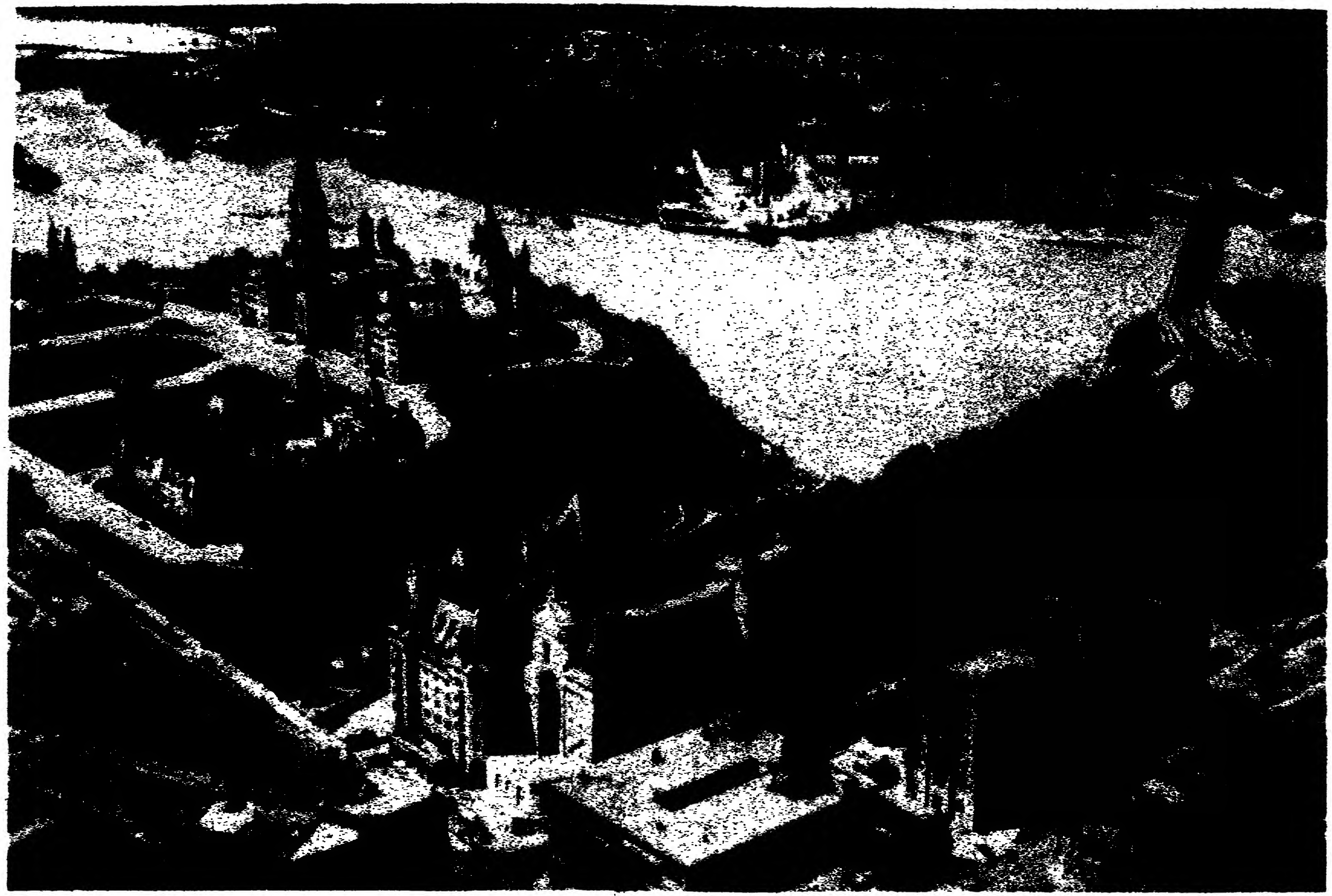
UPPER LEFT. FALSE GRAFT BETWEEN TWO RED MAPLES. FRICTION AT A BRANCH CALLOUS. THIS MAY LATER BECOME A TRUE GRAFT. UPPER RIGHT. FALSE BRANCH GRAFTS IN RED MAPLE. LOWER LEFT. CALLOUS IN BASSWOOD. MAY LATER BECOME A TRUE GRAFT. LOWER RIGHT. SMALL PINE GROWN INTO LARGER ONE.

sure of the soil and centrifugal growth kept the roots pressed firmly together and was sufficient.

Abrasion of trunks swaying in the wind has also been held responsible for grafting of stems. It seems undoubtedly to have been a factor in "false grafts," as well as true unions in New England second growth. Other influences are pressure of growth and adhesives, such as resins, gums and pitch which exude from abraded surfaces, taking the place of the orchardist's grafting wax. The original cause of many grafts has been the phototropic bending, storm damage, nibbling of cattle or weeviling which distorted the stems and branches and brought them into contact. There would appear to be a much higher frequency of grafts in pastured woodlands than in ungrazed areas. Branch stubs and swellings on the trunk often serve as initial points of contact. As the bark is scraped and bruised a callous develops and growth forms a larger and larger protuberance in healing the scar; this in turn aggravates the friction and eventually a true graft may result from the sticking together of the two callouses.

The upward bending of a lateral branch by correlation, following loss of the leading shoot by weevil injury may account for some of the grafts observed in white pine. Trees 8 to 10 inches in diameter growing a few feet apart are found joined 8 to 20 feet above ground, one trunk curving and disappearing into the other. In one case there are two such connections at a distance apart representing that of a branch whorl. A dead stub at the top, in continuation with the bole suggests the weeviled tip of the original independent tree. Clumps of pines growihg in pastures frequently become intergrown.

Sections through true grafts show complete union of conductive tissue so that the start of the connection is obscured. Grafting in trees, unlike that in human politics, is of negligible commercial importance, since timber in which it occurs is of relatively low value.



OTTAWA FROM THE AIR

THE PROGRESS OF SCIENCE

AMERICAN AND CANADIAN SCIENTISTS MEET IN OTTAWA

From June 27 to July 2 the American Association for the Advancement of Science will hold its first meeting in Ottawa, Canada. On four previous occasions the association met in Canada: in Montreal in 1857 and 1882, and in Toronto in 1899 and in 1921.

The Ottawa meeting will combine to an exceptional degree the advantages of a great gathering of scientists and an excursion into a region noted for its attractive scenery. Fortunately Ottawa is not in some distant part of our continent but within easy reach of the populous parts of the United States extending from New England to the Mississippi River and as far south of the Potomac and the Ohio rivers. It may be reached by through trains from the principal American cities or by automobiles over excellent roads.

Perhaps the greatest emphasis in the extensive and varied program centers in the second of the "Science and Society" conferences which will be presented under the general title "Science and the Future." The four sessions of these conferences have been assigned the character of General Sessions at hours almost completely free of competing attractions. Scientists have become acutely aware of the fact that the results of their investigations are having profound indirect, as well as direct, effects upon society, and they are beginning to accept a responsibility for examining into these consequences of their work. This broadening of the interests and feeling of responsibility of scientists is by no means limited to the association. It is perhaps even more acutely felt in European countries, particularly in England. At the present time discussions are very active in *Nature* on the question of establishing an organization for investigating the effects of the impact of science on society.

It would be unfair to other parts of the program at Ottawa to stress unduly the Science and Society conferences. It may be mentioned, however, that these conferences will be participated in by two Nobel prize winners and the president of the National Academy of Sciences, as well as by other eminent scientists from both sides of the Canadian border.

Broad symposia, often ranging freely across the usual boundaries that separate the sciences, are becoming more and more distinguishing features of the association. This evolution in the character of its progress is natural both because of the progressive subdivision and specialization of science and because the association through its fifteen sections and its 165 affiliated and associated societies covers essentially all of science. Its steadily increasing active membership now exceeds 19,000.

Among the symposia worthy of special emphasis is the one on "The Use of Isotopes in Biological Chemistry," which will naturally be participated in by physicists, chemists and physiologists. The fact that the isotopes of the elements are distinguishable from one another while retaining their chemical properties, places in the hands of scientists a new and extremely important means of following the physiological processes.

Another symposium in a related field is on "Micro-elements and Deficiency Diseases." One having more easily comprehended practical aspects is on "Nutrition Problem in North America." Perhaps this is related to the symposium on "Drought Resistance." In the field of medicine there is a symposium on "Medical Biochemistry" which will be participated in by Dr. Banting and other distinguished scientists who have reduced the world's woes by the discovery of the rôle of insulin in metabolism and methods of its isolation and purification. A different factor will play an important

PEACE TOWER OF THE PARLIAMENT BUILDINGS FROM EAST GATE

part in the symposium on "The Influence of Fire on Forests, Wild Life and Public Welfare." Of equal importance to biologists as well as bacteriologists and veterinarians is the symposium on "The Genetics of Pathogenic Organisms in Relation to Human Welfare." Another symposium of interest to biologists and conservationists is the symposium on "The Migration of Salmon—and Conservation."

Not every discussion at the Ottawa meeting will be on living things, at least directly, for there will be a symposium on "Atmospheric Ozone and Measurement of the Ultra-violet in Solar Radiation." Perhaps I should not state positively that this subject is not directly related to life, for it is quite within the bounds of possibility that ultra-violet radiations may be found to have very important direct and indirect effects upon living organisms.

The ability of British and Canadian

scientists to provide enjoyable excursions and social diversions that give a lighter touch to their meetings is well known. The arrangements at Ottawa made by the Canadian Committee promise to measure up to the high standards for such things that have become a tradition with them. Those from this side of the border will enjoy them and it is hoped will learn of their advantages in relieving from time to time the more serious nature of the programs of the association.

F. R. MOULTON,
Permanent Secretary

MEDALLISTS OF THE NATIONAL ACADEMY OF SCIENCES

AT its seventy-fifth annual meeting on April 25 to 27, 1938, in Washington, the National Academy of Sciences awarded medals to two scientists who have made noteworthy contributions to science. The medals were presented at the annual dinner by the president, who, in accord with established custom, spoke first on the status of the academy, on its recent activities in furthering progress in science and on the aid given the federal government in problems on which advice has been requested.

These addresses by the president reflect the more important trends in current science and record, in a general way, the service rendered to the government by the academy. They are important statements, clearly written and authoritative. In his address President Lillie commented briefly upon the fiftieth anniversary celebration of the academy a quarter of a century ago and referred to some of the events since that time, including the world war, and to the services of the academy as scientific adviser of the government during that period. He alluded to the establishment and increasing importance of the National Research Council; to the steady growth of "consciousness of social and political responsibility that attaches to scientific leadership in our times"; and to the increasing realization of the importance of our foreign relations. In keeping with this realization the Royal Society of London and the National Academy of Sciences have recently proposed the Pilgrim Trust Lectureship. To quote Dr. Lillie:

> Under the terms of this relationship it is agreed, on the invitation of the Royal Society, that the Pilgrim Trust Lecturer shall be appointed annually; in alternate years an American scientific man to be appointed by the Royal Society to give the lecture in London, and a representative of British scientific men to be appointed to give the lecture in Washington. This arrangement is supported by a grant of 250 guineas per year for a period of six years by the Pilgrim Trust. I am happy to announce that the Royal Society has appointed as the first Pilgrim Trust lecturer our fellow member Dr. Irving Langmuir, to speak in London in December of this year.
>
> This very welcome consummation has also been the occasion of renewal of pledges of mutual hospitality to our respective members in London and in Washington. The President of the Royal Society alluded most cordially to this arrangement in his anniversary address last November. We join with him in the wish and expectation that science, which stands apart from all nationalism, may become an increasingly strong bond between the nations of the earth.

At the close of the president's address the medals are presented. The president calls upon the chairman or other member of the Trust Fund committee, recommending the award, to state briefly the reasons for the selection of the medalist, who in turn expresses appreciation of the honor bestowed upon him. The ceremony reflects much of human interest and affords opportunity for public expression of the value of the work of the medalist to science.

THE AGASSIZ MEDAL FOR OCEANOGRAPHY

The Agassiz Medal was awarded to Dr. Edgar Johnson Allen, director emeritus of the Plymouth Laboratory of the Marine Biological Association of the United Kingdom, Plymouth, England, "in recognition of his personal researches on marine biology and the great influence which he has exerted on the study of

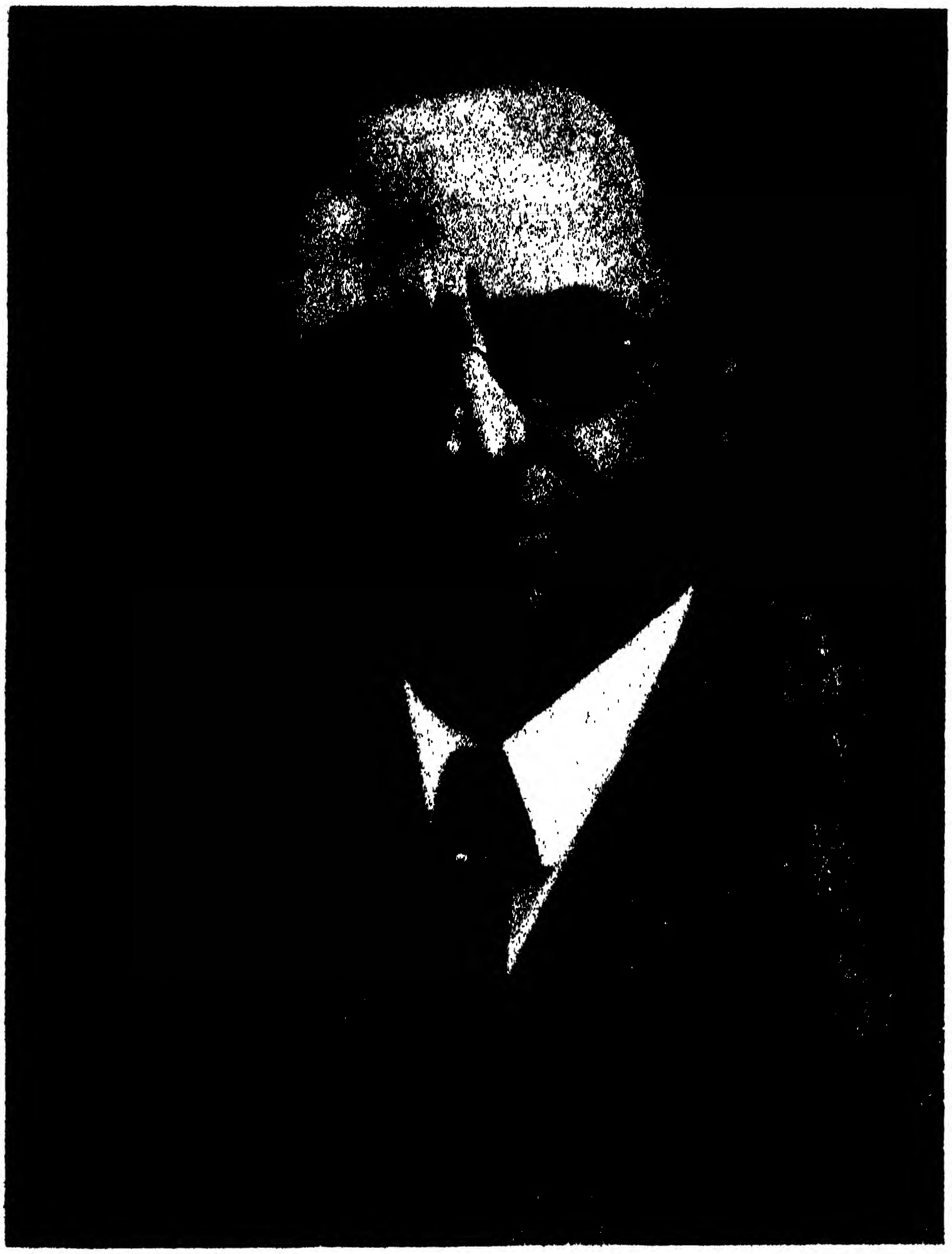
DR. E. J. ALLEN

marine organisms in the relation to the marine environment."

Dr. E. G. Conklin, a member of the Murray Fund committee, which recommended the award, stated in his presentation speech that

Dr. Allen has been in a very real sense the creator of this laboratory, which is one of the most important in the world. A British colleague has written that "it was universally regarded as a white elephant when Dr. Allen took the directorship and turned it into a highly efficient research institution." In 1902 the Plymouth Laboratory was placed in charge of the British work on the International Commission for the Exploration of the Sea with Dr. Allen in charge of investigations. These investigations have been carried on there ever since and include studies on hydrography, meteorology, currents, plankton and other marine organisms. By means of these studies the circulation of oceanic waters in the English Channel and North Sea have been charted, and the movements of swarms of plankton and their relation to food fishes have been determined.

For his contributions to oceanography in the creation and wise direction of the Plymouth Laboratory; for his unselfish cooperation with hundreds of investigators at the laboratory for the past forty-two years; for his active work in connection with the International Commission for the Exploration of the Sea; for his direct contributions to the study of the life of the sea and its relation to human welfare, the committee



DR. W. R. WHITNEY

on the Agassiz Medal takes particular pleasure in recommending for the award at this meeting a friend of Sir John Murray and Alexander Agassiz—Dr. Edgar Johnson Allen.

Dr. Allen was unfortunately not able to receive the medal in person, and Leander McCormick-Goodhart, Esq., of the British Embassy, accepted it gratefully for transmission to Dr. Allen through diplomatic channels.

The Public Welfare Medal

The Public Welfare Medal from the Marcellus Hartley Fund was awarded to Willis Rodney Whitney, of the General Electric Company Research Laboratories, Schenectady, New York, "in recognition of his outstanding work in the fundamentals of scientific research for the public good."

Dr. A. W. Hull, chairman of the committee that proposed the award, in his presentation address referred briefly to Dr. Whitney's

outstanding contributions to human welfare in the field of electric lighting, and in the use of high-frequency electric currents for curing diseases such as paresis, arthritis and bursitis.

His greatest contribution, however, is as organizer and director of scientific research. Not the common organizer. The very term does him injustice. His organization was a growth rather than a creation. It grew so gradually that it is

difficult to give any date when it became an organization, except the date, November, 1900, when the M.I.T. professor began sharing his time with General Electric, spending two days each week in Schenectady.

The laboratory that has grown up under his leadership is still small, scarcely 300 men. Its influence for public welfare is not so much *their* contributions to science and industry, as *his* contribution, as a pioneer in industrial research, in demonstrating what was by no means obvious, that pure research can be successfully carried on in an industrial laboratory, with profit and untold benefit to mankind.

For this eminence in the application of science to public welfare I commend to you Dr. Willis Rodney Whitney, pioneer of industrial research.

Dr. Whitney, in gratefully accepting the medal, expressed sincere appreciation of the honor bestowed on him as "representing a living active group of research men."

In our particular research-group our duty is to help counteract the effects of obsolescence of electrical products and prevent interruption of employment of large groups by actively aiming at new electrical unknowns.

In such work we also found, somewhat as a by-product, that our research men could contribute to growing science by publishing their results. They have now published about one thousand scientific articles. These, I like to feel, are contributing thus to general knowledge and public welfare.

F. E. Wright,
Home Secretary

NATIONAL EXHIBITION OF THE WORKS OF JOHN J. AUDUBON

One hundred and four original paintings and drawings by John James Audubon, the celebrated artist-naturalist of the nineteenth century, were displayed at the Academy of Natural Sciences of Philadelphia from April 26 until June 1.

The showing of this collection marked the one hundredth anniversary of the publication of "Birds of America," one of natural history's proudest monuments. These elephant folio volumes were completed in London, in 1838, seven years after Audubon had been elected a member of the academy in 1831.

The exhibition was arranged by divisions so that the visitor would be able to visualize the artistic progress Audubon made in his lifetime of portraying animals. The first section was devoted to his earliest French drawings. Though they are in many cases crude and awkward representations, all of them show evidence of his remarkable eye for color.

Following this section were those showing paintings made while a resident at "Mill Grove" near Philadelphia, in Kentucky and in Louisiana. In this later division Audubon begins to reach the full heights of his artistry. His birds have become tremendously alive and assume colorful lifelike poses.

This period is likewise important as it marks the artist's debut as a portrait painter and his first experiments in oil. An interesting portrait in chalk was that of General and Mrs. Lytle, done in 1821, at Cincinnati. By such sketches as these Audubon was able to gain a meager livelihood and continue his work on the "Birds of America."

Two other divisions devoted to paintings were exhibited—those done while in England and America between 1826 and 1838 and his Quadruped paintings done from 1838 until death in 1851. The Quadruped paintings have long been overlooked by many Audubon admirers. The artist is particularly facile in drawing small animals, and his talent was never better demonstrated than in the drawing of "Richardson's Squirrels."

In addition to the paintings, the academy's exhibition showed a comprehensive collection of Auduboniana, such as letters, journals and editions of his works, as well as copper plates and engravers' proofs. To many, the original subscription list with the names of the subscribers to the parts of the elephant folios of the "Birds" is of outstanding interest. Here we see evidence that Audubon, though a business failure in his youth, was able in maturity to engineer one of the most gigantic jobs of publishing ever undertaken. Two hun-

AUDUBON IN THE FIELD
OIL PAINTING BY HIS SON, JOHN W. AUDUBON.

dred and seventy names appear on the list, which is headed by George IV and the Duchess of Clarence, and, in addition, contains the names of Baron Cuvier, Daniel Webster and Henry Clay, Jr.

The method Audubon followed in making his drawings for publication was shown in an exhibit of the four sketches and drawings of the "Soft-Haired Squirrel." Here he first made a rough pencil sketch, then individual finished

THE GREAT COCK OR WILD TURKEY

AN OIL PAINTING WHICH FORMERLY HUNG IN THE HOUSE OF AUDUBON AT MINNIE'S LAND AND WAS LENT THE EXHIBITION BY AUDUBON'S GREAT GRANDSON, VICTOR M. TYLER, NEW HAVEN, CONN.

sketches of the two animals and finally one of the background with the spaces the animals were to be placed in indicated for the engraver.

One of the simplest but most graphic exhibits in the show is a small map marking the courses of Audubon's travels throughout America, frequently by foot or flatboat. This is a chart of one man's intense fight for success. Twelve times during his life he crossed the Atlantic and many weary miles were traveled alone and unknown throughout Europe and America in the not pleasant rôle of salesman for a work difficult to sell to scientists, much less total strangers.

A comprehensive catalogue of the exhibition has been prepared, which aside from containing information on all the items in the show, has an introductory essay prepared under the direction of Dr. Witmer Stone which discusses Audu-

bon's association with the academy. The catalogue is illustrated with ten half-tone engravings and may be purchased, postpaid, by sending 25 cents to the academy, 19th Street and The Parkway, Philadelphia.

More than thirty different museums, libraries and collectors, including three descendants of Audubon and a descendant of Robert Havell, the English engraver of the "Birds of America," lent material to the exhibition. Particular care was taken to gather from all parts of America interesting Audubon items so that the exhibition would be truly national in scope.

In presenting its exhibition, the academy attempted to make an appreciative public fully aware of Audubon's talent.

JOHN H. FULWILER

THE HALL OF SCIENCE AT THE SAN FRANCISCO FAIR

AN attempt will be made to interest a wide public in the advancement of science through exhibits in the Hall of Science of the 1939 Golden Gate International Exposition in San Francisco; institutions and individuals are cooperating on a large scale. Where it is possible, fully equipped research laboratories will be open for inspection. Elsewhere, special displays will reproduce the conditions of plant and animal life on simplified or enlarged scales. Biology, chemistry, psychology, physics and medicine will be represented by specialists in their fields.

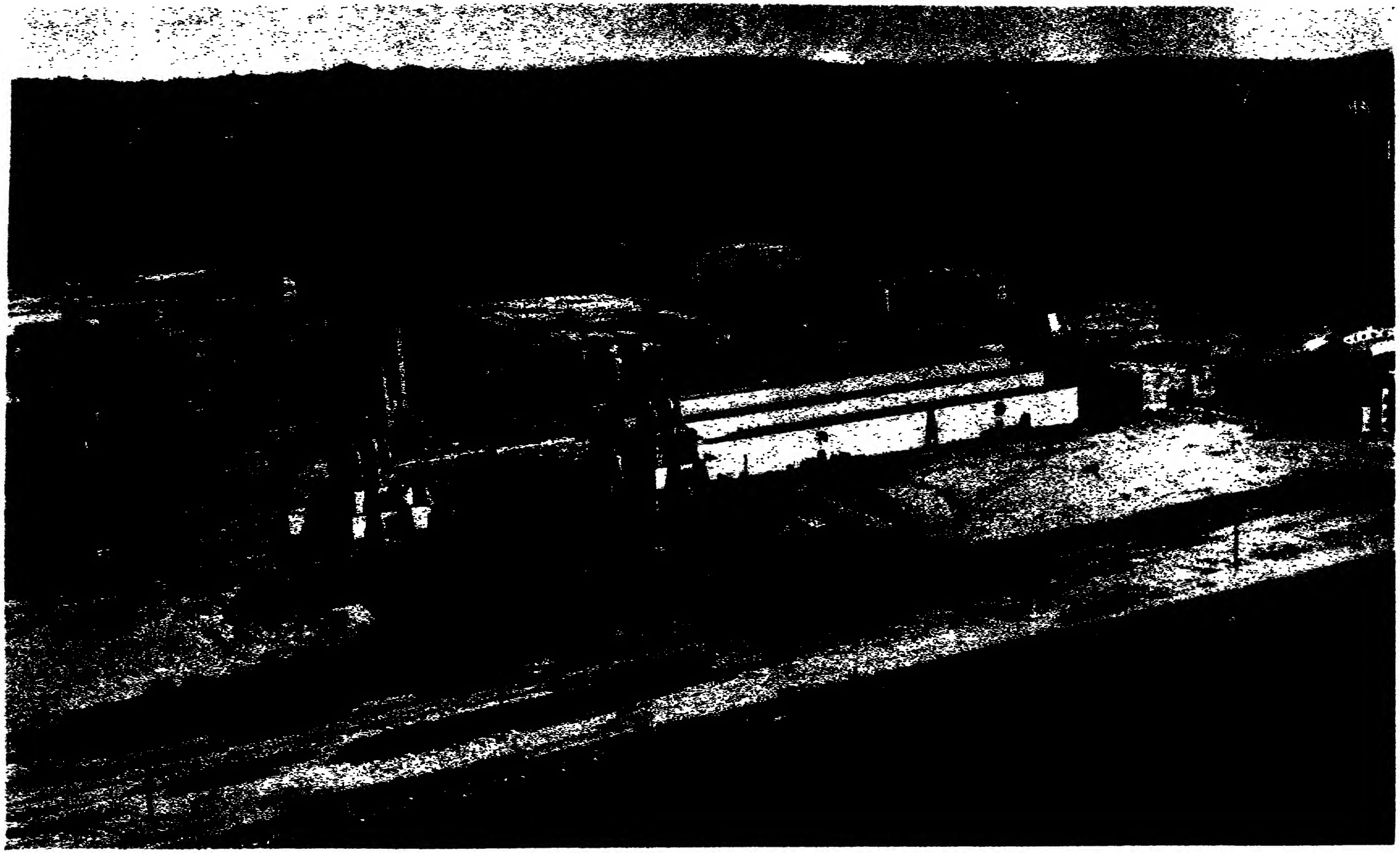
As a part of the exhibit of the University of California, on which $200,000 will be expended, a full-size model of the 220-ton atom-smashing cyclotron, now being erected at its radiation laboratories in Berkeley, will be seen in simulated operation. All the details of its construction are to be accurately reproduced. Instead of the invisible, dangerous neutrons that ordinarily whirl about in the vacuum chamber, however, steel balls will wind slowly outward in spiral paths to illustrate their motion. Actual samples of radioactive material produced by the cyclotron will be demonstrated behind ample shielding to protect observers.

Another demonstration from the University of California will be the story of life from the top of the highest mountain to the sea bottom. To present a simple, complete picture, representations of plants and animals will be placed at the proper heights at the side of a miniature mountain 35 feet high. Entering a shaft located inside the mountain, visitors will descend to a model bathosphere suspended among models of deep-sea life as they would appear to an observer beneath the ocean. Near-by will be shown miniature trawlers, oceanographic vessels and other craft with equipment for recording deep-water temperatures, depths and for collecting samples.

In the biological division of the Hall of Sciences the life cycles of the salmon and eel are to be realistically portrayed, as well as specimens of other fish in their natural habitats. Specially designed lighting effects will be employed for a closer resemblance to nature, and trained speakers will be on hand to lecture at scheduled hours.

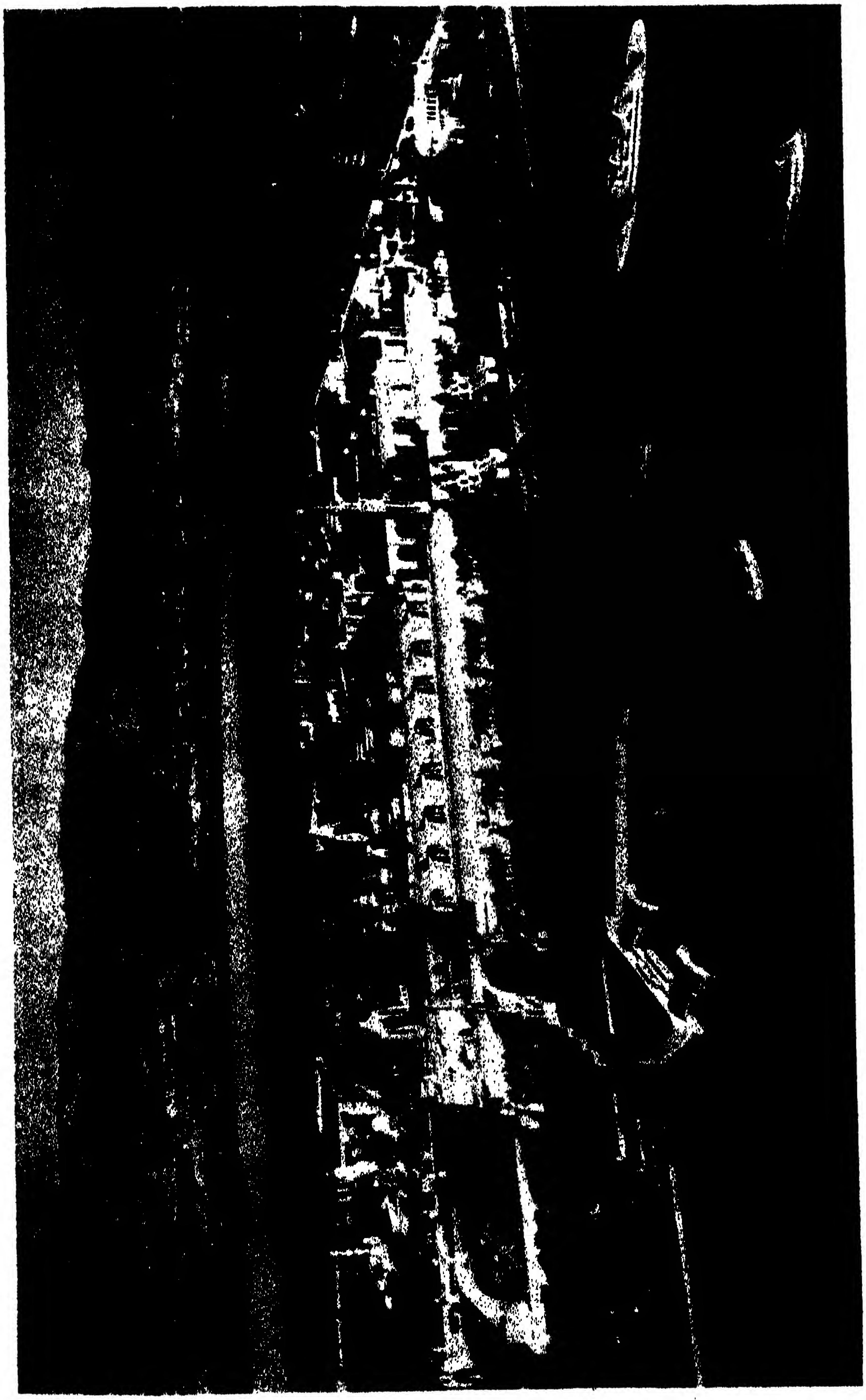
At the plant exhibit the roots of growing plants will be seen extending into transparent bowls of water treated with soluble nutrients. By regulating the nutrient formulas in such a way as to withdraw different fertilizing elements from the food of specimens, the consequences of such defects on growth and health can be readily observed. Special devices will magnify the internal structure and life processes of plants.

The directors of the Hall of Science intend to demonstrate as large a number of subjects of scientific interest as possible and in such a way that they will be appreciated by visitors who have no special technical knowledge. Bacteria operating in different media will produce a variety of products—among them perfumes, flavorings, medicines and hormones. The public will be able to see the production in test-tubes of fats, proteins



AN AERIAL VIEW OF EXPOSITION BUILDINGS UNDER CONSTRUCTION

IN THE FOREGROUND THE ELEPHANT TOWERS, FLANKING THE MAIN ENTRANCE, ARE TAKING DEFINITE FORM. BEYOND, IN THE COURT OF HONOR, IS THE 400-FOOT TOWER OF THE SUN. AT THE EXTREME RIGHT CAN BE SEEN A PART OF THE $1,000,000 ADMINISTRATION BUILDING, TO BECOME THE TERMINAL BUILDING WHEN TREASURE ISLAND REVERTS TO AN AIRPORT AT THE CONCLUSION OF THE EXPOSITION. IN THE BACKGROUND ARE THE CITIES OF BERKELEY AND OAKLAND.



A MODEL OF THE GOLDEN GATE INTERNATIONAL EXPOSITION

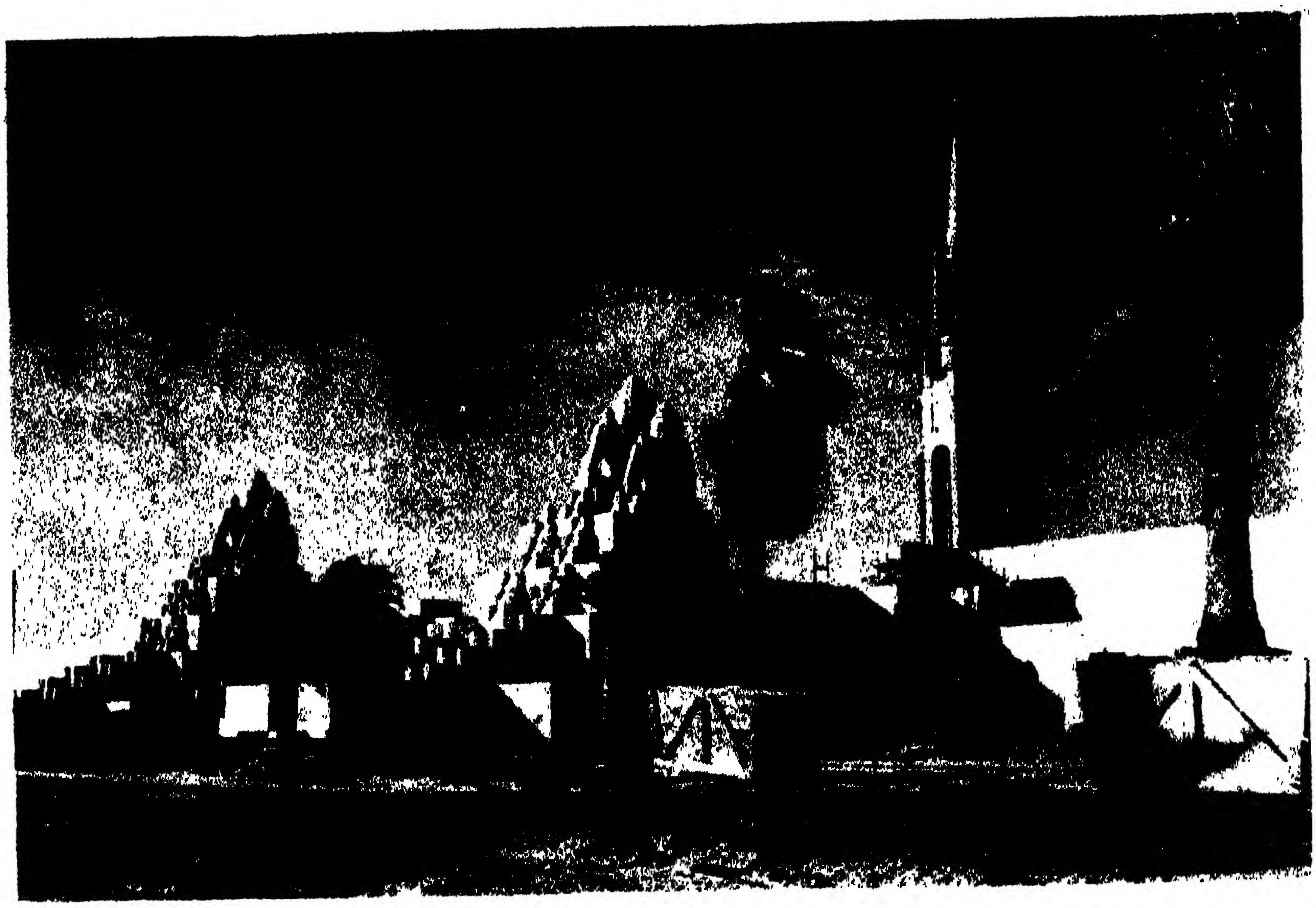
TO BE HELD ON TREASURE ISLAND IN SAN FRANCISCO BAY IN 1939. THE MODEL IS 16 FEET LONG, 7 FEET WIDE AND IS BUILT ON A SCALE OF 150 FEET TO THE INCH. IT WEIGHS MORE THAN A TON. THE HALL OF SCIENCE IS IN THE CENTER OF THE PICTURE EXTENDING TO THE LEFT FROM THE TOWER. THE BERKELEY HILLS AND THE BUILDINGS OF THE UNIVERSITY OF CALIFORNIA CAN BE SEEN IN THE BACKGROUND.

and sugars from non-organic materials. Sugar will be synthesized from carbon dioxide and water and, in turn, treated with nitrogen to form a protein.

Thirty outstanding research laboratories have volunteered to illustrate the story of progress in the treatment and prevention of disease. Led by the American Medical Society, the Mayo Clinic and the American Society for the Control of Cancer, they will present a picture of contemporary advances in medicine and related fields. A complete health exhibit will demonstrate the importance of proper nutrition, vitamins, sanitation and other methods of public health.

Mechanical models and a transparent man will demonstrate human physiology and the functioning of the bodily organs in conjunction with the effects of drugs and the digestion of food. Close by will be shown the latest practices in cancer treatment, plastic bone surgery, the uses of radium, the x-ray and insulin and an outstanding embryological display, "How Life Begins."

Among others, the American Dental Association exhibit will be one of the most complete of its kind, combining a history of past and recent progress with an illustration, by means of model heads and jaws, of the effects of evolution, racial differentiation and diet on dental structure.



THE TOWERS OF TREASURE ISLAND

AT THE LEFT ARE THE MASSIVE TWIN ELEPHANT TOWERS FLANKING THE MAIN ENTRANCE TO THE FAIR; AT THE RIGHT IS THE 400-FOOT TOWER OF THE SUN SURMOUNTED BY A GOLDEN PHOENIX. IN THIS TOWER WILL BE A CARILLON OF FORTY-FOUR BELLS.

It is the intention of the directors of the Hall of Science to give visitors with no special training a clearer understanding of the physical and biological sciences. To this end leading universities throughout the country are cooperating notably—the University of California, Stanford University, the California Institute of Technology, the University of Southern California, Harvard University, the University of Oregon and the University of Washington.

MORT FRIEDLANDER

THE SCIENTIFIC MONTHLY

AUGUST, 1938

PROLACTIN, A PRODUCT OF THE ANTERIOR PITUITARY, AND THE PART IT PLAYS IN VITAL PROCESSES

By Dr. OSCAR RIDDLE

DEPARTMENT OF GENETICS, CARNEGIE INSTITUTION OF WASHINGTON, COLD SPRING HARBOR, N. Y.

I

THE subject-matter of this paper includes more than the title suggests, and it may be of interest for any one of three reasons. *First:* the things recently learned about the several products of the anterior pituitary gland will help the present and all future generations of mankind to control some of the abnormality and disease that now attend the birth and life of man. *Second:* This new knowledge has bearing on a philosophical question—so, in the years ahead, it will creep into the mental outlook of the one living species that seeks to know itself. A few substances which are formed only in the pituitary gland are now surely known to be powerful agents for the coordination and control of some highly complicated life mechanisms—mechanisms which have long seemed too peculiar and complex for control by the nervous system. Once we see how the several pituitary substances act and interact these hitherto mysterious processes and mechanisms become simpler and comprehensible; and thus the new knowledge of these substances brings further evidence for a purely *naturalistic* basis of life at a high or human level. *Third:* To me it seems that just now, and for us all, there is both challenge and interest in the circumstance that though these pituitary substances serve so importantly in our lives their very existence has remained unknown and unsuspected until our own day. Our acquaintance with the services performed by this gland began after nearly all of my immediate readers were born, and the very beginning of our knowledge of the specific products of this gland falls almost within the last decade.

It seems well to pursue our brief consideration of the several products of the pituitary gland, and to acknowledge at once the incompleteness of our knowledge of them. We do not now know the precise number of different substances prepared and released into the blood by this gland; our information concerning the actions of each of these hormones is quite incomplete; and we have only fragmentary knowledge of the chemical nature of any one of these products. Yet, despite these great limitations, there is good reason to believe that a decade of investigation has provided the following items of important information: (*a*) Recognition of the several life processes which are most markedly affected by these products; (*b*) establishment of the fact that at least three or four distinct products are formed in and released by the anterior pituitary; (*c*) classification

of these products as of protein (or polypeptid) nature, and of a type known as hormones, and—most remarkable of all—hormones which commonly act upon other hormone-secreting glands; (*d*) finally, it is becoming clear that in large measure these hormones of the pituitary and the hormones of the glands which they call into action act largely as a self-regulating system—and that to one or another degree these pituitary hormones act upon the nervous system while the nervous system likewise shares in regulating the output of one or more of these hormones.

As a total result of this decade of study of the actions and interactions of these particular hormones in the bodies of higher animals a purely natural basis for some of the most mysterious performances and adjustments of our own bodies has become evident. Now, for the first time in the long history of man, human beings partly know a series of substances which largely control the rhythms of reproduction, the fuller expression of growth and some aspects of temperament and behavior. The brain and the anterior pituitary gland are now marked as the truly basic sources of the competence of man. It is not wholly without point to reflect that till now mankind has made its history—its conquests, its arts, its literature, its laws, its religions, its philosophies—while wholly ignorant of one of the two physical sources from which the abilities of an individual human being are derived.

The location, the structure and the closer associates of this master gland deserve notice. Quite like the older part of the brain the pituitary is not formed of separate right and left halves, but is a single or unpaired organ placed very close to the floor of the brain. The anterior pituitary gland is also pressed closely against another smaller organ called the posterior pituitary gland. This posterior gland prepares or secretes its own hormones—two of which are now fairly well known. Moreover, a very small amount of still another tissue lies between the two glands just mentioned and this tissue is usually known as the intermediate pituitary, while the hormone it produces is called "intermedin."

When one suitably prepares and magnifies some of the cells of the anterior pituitary gland three rather distinct kinds of cells can be found; their differences become much clearer after they have all been washed with certain solutions containing color or stain. In general, there is reason to think that those cells which remain uncolored after such a bath in colored fluid are resting cells—cells not actively producing any hormone—and also reason to believe that very small granules which assume a bluish color are granules associated with a hormone which is called "gonad-stimulating" hormone. Finally, there is reason to believe that other very small granules which assume a pink or eosin color are closely associated with the hormone "prolactin."

If the two kinds of colored granules just mentioned each contained only one hormone the task of investigating and of describing this subject would be greatly simplified. Unfortunately, however, when the blue granules are dissolved or extracted from the cells in which they lie we seem to obtain two or more somewhat different products, each having an action upon the sex glands but upon different parts of that gland. That particular product which acts upon the follicles of the ovary and the tubules of the testes is known as "follicle-stimulating" hormone (FSH), while another product which acts upon the hormone-secreting cells of ovary or testis is called "luteinizing" hormone (LH). Still worse for us all, our definite knowledge of these two products—if indeed they are two wholly distinct things—is complicated by several things only one of which will be considered here. It has been observed

that certain effects which can be produced by larger doses only of either follicle-stimulating or of luteinizing hormone, can also be produced by extremely minute amounts of a mixture of the two substances. In other words, when present together these two substances show the remarkable thing called "synergism" —or multiplication of effect—a property which will be met more than once in the present discussion.

It is likewise notable that the eosin-colored granules of which we have spoken probably do not represent prolactin alone. In addition, the product or extract obtained from these cells (actually the extracts are from all of the pituitary cells) perhaps includes "thyrotropin" which has special power to make thyroid glands grow and work, and another substance, "adrenotropin," which in like manner makes the adrenal gland (cortical part) grow and work. Here, too, among the members of this group of products, we again find those curious effects called synergisms. For example, in certain places and circumstances it has been observed that prolactin and thyrotropin have multiplied, rather than added, their separate capacities to produce heat, and also their separate abilities to produce bodily growth. It is also probable that prolactin and adrenotropin form a synergistic pair for increasing the store of glycogen and fat in the liver.

The writer has become so impressed with the number—and with the great functional importance—of synergized reactions among the pituitary hormones that, in the above statement and for the first time, he here ventures to use the observed fact of synergism between two pituitary products as evidence for their origin from the same type of pituitary cell. This venture is supported by several kinds of observations. We here note merely that it is well known that cells of the one type may display all evidence of very rapid hormone production at a time when cells of the other type give much or all evidence of complete inactivity. These useful synergisms of bodily activity would be present more continuously, and they would evidently be subject to a more automatic control, if the members of the synergizing pair were produced concurrently within the same type of pituitary cell.

II

Some of the actions of the several pituitary hormones, and of prolactin in particular, can be illustrated by means of photographs or other graphs. Such illustrations will considerably assist an understanding of a series of bodily changes which should now be examined more closely. Important clues to the general functions of the pituitary gland have been obtained by the surgical removal of the gland, and the first operations of this type were made in Europe more than three decades ago. In more recent years and in several laboratories it was found that when this operation—it is usually called hypophysectomy—is performed on real young animals the results are very striking.

The three dogs of Fig. 1 are all from the same litter. The two small ones had their pituitaries removed when 5 days old, and they grew but little thereafter till this photograph was taken 4 months later. On the same day the pituitary of the large dog was exposed and touched, but left in place. According to Dr. Kapran, of Kiev, Russia, who made that study and published this photograph a year ago, the dog subjected to this "sham" operation grew as well as did its litter mates which were not operated at all. The smaller rat of the pair shown here was deprived of its pituitary when 35 days old and when its weight was 70 gms. At the time this photograph was taken, 90 days later, its weight was only 75 grams, though its unoperated litter mate had meanwhile become the 200 gram rat

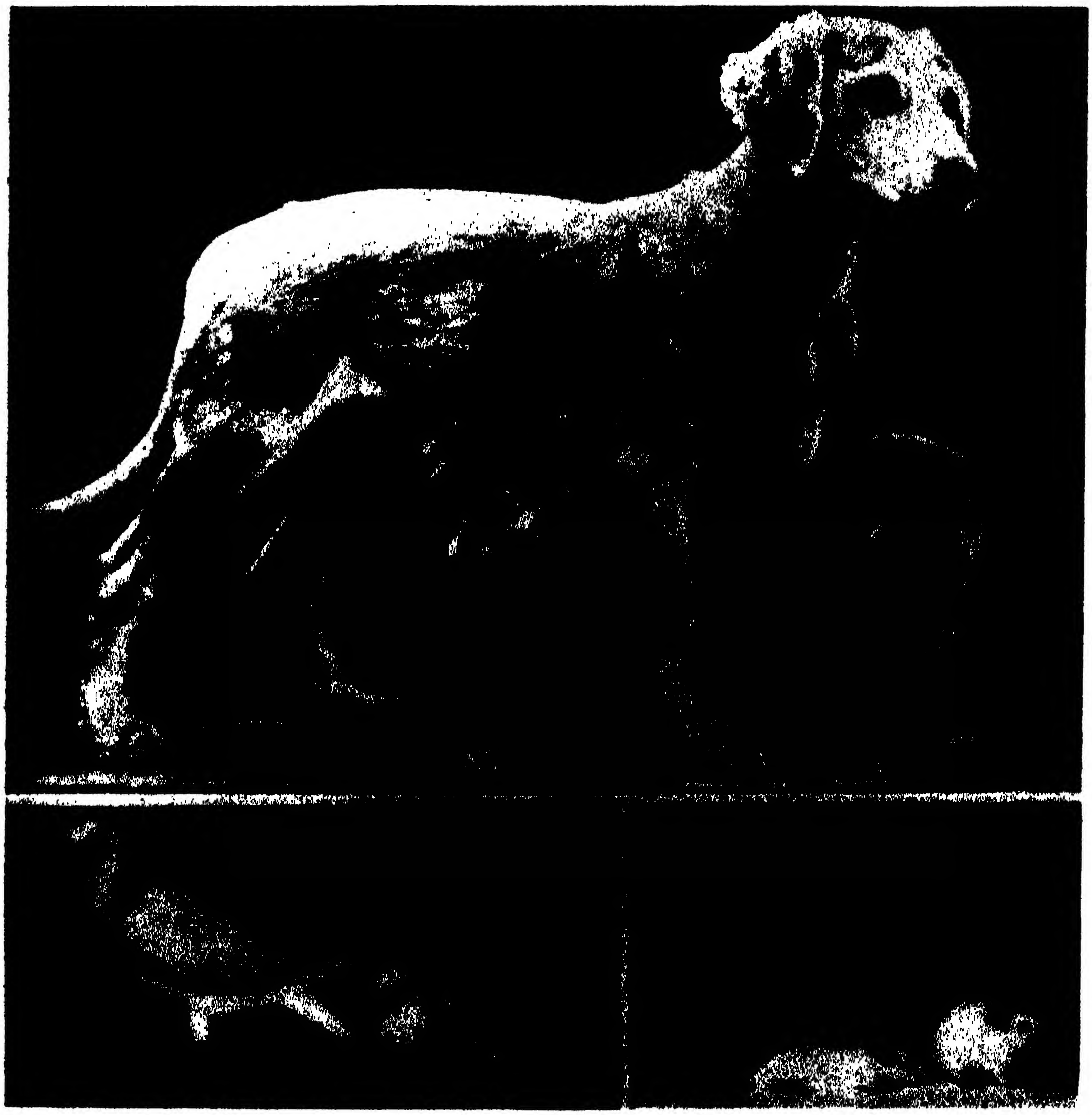


FIG. 1. EFFECTS OF PITUITARY REMOVAL ON BODY GROWTH IN ANIMALS
THE TWO SMALL PUPS WERE OPERATED WHEN 5 DAYS OLD AND GREW LITTLE THEREAFTER THOUGH THEIR LITTER MATE IS SHOWN TO HAVE MADE GOOD GROWTH WHEN ALL WERE PHOTOGRAPHED 4 MONTHS LATER (KAPRAN). THIS OPERATION LIKEWISE STOPS GROWTH IN YOUNG PIGEONS AND RATS.

of the photograph. The two pigeons shown are litter or clutch mates. The pituitary of the smaller one was removed 22 days before this photograph was taken, and though the feathers of this bird continued to grow its body weight remained practically unchanged. In the case of pigeons at least it has been shown that prolactin has a large share in causing the body to grow to normal size, and also to attain supernormal size. In animals generally it has hitherto been customary to ascribe the promotion of bodily growth to a special "growth" hormone.

It is unfortunate that you can not see on these same or other photographs the striking changes that occurred in certain internal organs of all these animals after they lost their pituitaries. Some of those vital internal organs suffered so much disorganization or atrophy that the really surprising thing is not that thereafter

their bodies ceased to grow, but rather that they were able to maintain their body weight following such injury to some of their vital organs. Preceding our own studies on this subject it had been shown in several laboratories that the thyroid gland, the sex glands, and the adrenals of rats, dogs and tadpoles are quickly and greatly damaged by the removal of their anterior pituitary glands. In pigeons we find that the liver and intestine also suffer more than does the body in general, and that prolactin—perhaps largely through its stimulation of appetite—especially restores these organs.

The first-found vital processes that could be assigned definitely to prolactin related to the formation of crop-milk in pigeons and to the stimulation of milk secretion in mammals. It was at this point in our knowledge of this hormone that it was given the name prolactin. When this hormone is injected into pigeons, even into very young ones, the sides of the crop-wall rapidly thicken and begin to secrete the so-called "milk" which all parent pigeons use in feeding and rearing their young. In Fig. 2 one notes the curious fact that not all of the crop-wall can be thickened and activated by prolactin—but only the two lateral pouches. In the other segments of Fig. 2 it can be seen that the mature, non-secreting mammary gland cells of the rabbit—such as are shown at the extreme left—can be made to secrete milk following the injection of prolactin; this is indicated by the enlarged, hazy, milk-filled bulbs of the central figure. And, the figure at the extreme right gives evidence that other pituitary hormones (FSH, thyrotropin, etc.) than prolactin will not stimulate those prepared cells to proceed with the secretion of milk. This capacity of prolactin to stimulate milk secretion has been observed in many mammals, including women. Other investigators have recently obtained evidence that the adrenal glands supply something that must accompany prolactin in order that milk secretion may occur and continue.

Later studies made with our several associates have shown that prolactin has still other actions which are, in many respects, of much greater consequence than the two restricted or local actions just described. A generalized or widespread action of prolactin is well illustrated by the effect of this hormone on the rate of heat production in pigeons. Thyrotropin was found to have no action on the heat production of pigeons whose thyroids had been removed; but in such pigeons (measured at 30° C.) prolactin definitely increased the rate of heat production. It was also learned that pigeons whose heat production was first much decreased as a result of the removal of their pituitaries show very great increases in their heat production (basal metabolism) after injections of prolactin. We do not yet know which organs of the body are thus stimulated by prolactin, but there is some reason to suspect that the intestine, liver and pancreas, and perhaps the adrenals, are especially involved.

Fig. 3 illustrates a part of the action just described. But it more especially deals with an additional aspect of this action of prolactin—an aspect which is of extraordinary interest. Here prolactin is observed to synergize, or augment, an effect on the basal metabolism which it shares with another pituitary hormone. It was first fully shown that the injection into doves of either thyrotropin alone or prolactin alone would increase their rate of heat production; also, that higher dosage of either of these hormones had greater effect than lower dosage. The curves of Fig. 3 show that a certain level of dosage of the two hormones given separately produced, in each case, a moderate increase in the metabolism of groups of doves injected for 2 and 6 days. When, however, only one half of the amount of hormone previously and separately used was given in combination, this

combination caused a much greater increase in the basal metabolism. Thus prolactin and thyrotropin have been observed to show a synergistic action on the basal metabolic rate of these animals.

In the light of what has just been noted concerning a synergism of prolactin and thyrotropin on heat production, and in view of the debated problem of the means by which the pituitary gland contributes so greatly to the processes of bodily growth, it is necessary to consider the action of these same hormones on growth in the dwarf mouse. By selecting from groups of these peculiar dwarfs only individuals proved incapable of further growth when left without treatment it was found that either prolactin or thyrotropin would induce some or much additional growth in these individuals. Of still greater interest was the observation that concurrent administration of minute amounts of the two hormones results in a marked synergism of the growth response in these animals. It has become clear that prolactin shares in the promotion of bodily growth in at least such animals as doves, pigeons and dwarf mice.

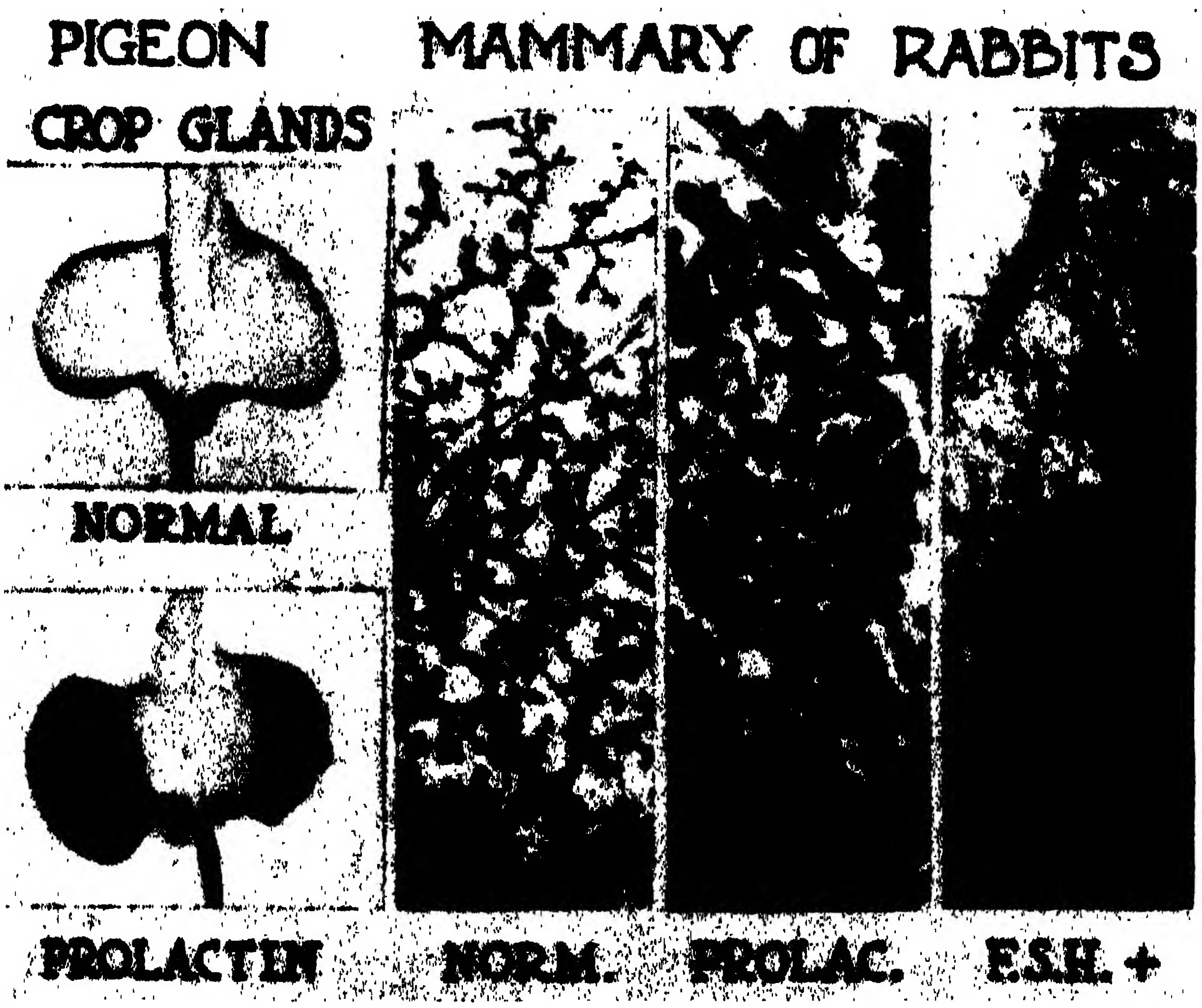


FIG. 2. SHOWING THE ACTION OF PROLACTIN ON CROP-SACS AND ON MAMMARY GLAND

WHEN UNSTIMULATED BY PROLACTIN THE WALLS OF THE PIGEON'S CROP ARE VERY THIN AND TRANSPARENT. BUT EITHER THE RELEASE OF PROLACTIN BY THE BIRD'S OWN PITUITARY OR INJECTION OF PROLACTIN FROM A HEN, A CALF OR A WHALE CAUSES THE LATERAL POUCHES OF THE CROP-WALL (AND THESE PARTS ONLY) TO THICKEN GREATLY AND PRODUCE "PIGEON MILK." AFTER THE CELLS AND DUCTS OF RABBIT MAMMARY GLANDS HAVE DEVELOPED PROPERLY 2–4 INJECTIONS OF PROLACTIN WILL CAUSE THEM TO FORM AND STORE MILK. OTHER PITUITARY HORMONES DO NOT STIMULATE MILK SECRETION.

At the moment it is not possible to state the extent to which prolactin affects the disposition of sugar and carbohydrate in the body; some investigators think that pure prolactin does not possess an action of this kind. For several years it has been known that some product or products of the anterior pituitary tends to

increase the amount of sugar in the blood of most animals; and everyone knows that under certain conditions the blood sugar of man increases greatly in amount, the kidneys excrete it, and a condition (still more involved) known as diabetes is established. There has been and there now is much discussion and investigation directed to a determination of the particular anterior pituitary hormone or hormones responsible for this blood sugar-raising and "diabetogenic" action.

The purposes of this communication require, despite uncertainties surrounding the subject, a brief statement of our own studies on this question. The abilities of the several available types of relatively purified hormones to increase the amount of sugar in the blood of fasting rabbits, rats, doves and pigeons has been examined. Of the various hormones used prolactin has most consistently increased the sugar content of the blood (glycemia) of these animals (except rats), though the increases are moderate in amount—usually only 10 to 40 per cent. In pigeons the typical glycemic action of prolactin is wholly absent during the first several hours, and under daily dosage it progressively increases for at least 5 days and this is accompanied by an increased deposit of glycogen and fat in the rapidly enlarging livers of these animals. The curves of Fig. 4 show that a single injection of highly purified prolactin causes in non-fasting rabbits a slow and fairly prolonged increase in the sugar of the blood. The fact that the increase does not reach its height within an hour or two, and does not quickly disappear, serves to exclude the possibility that this effect was produced by traces of posterior lobe hormones instead of by prolactin.

Adrenotropin, which can not now be prepared free from prolactin, has usually failed to give an indication of a similar and separate action on the blood sugar

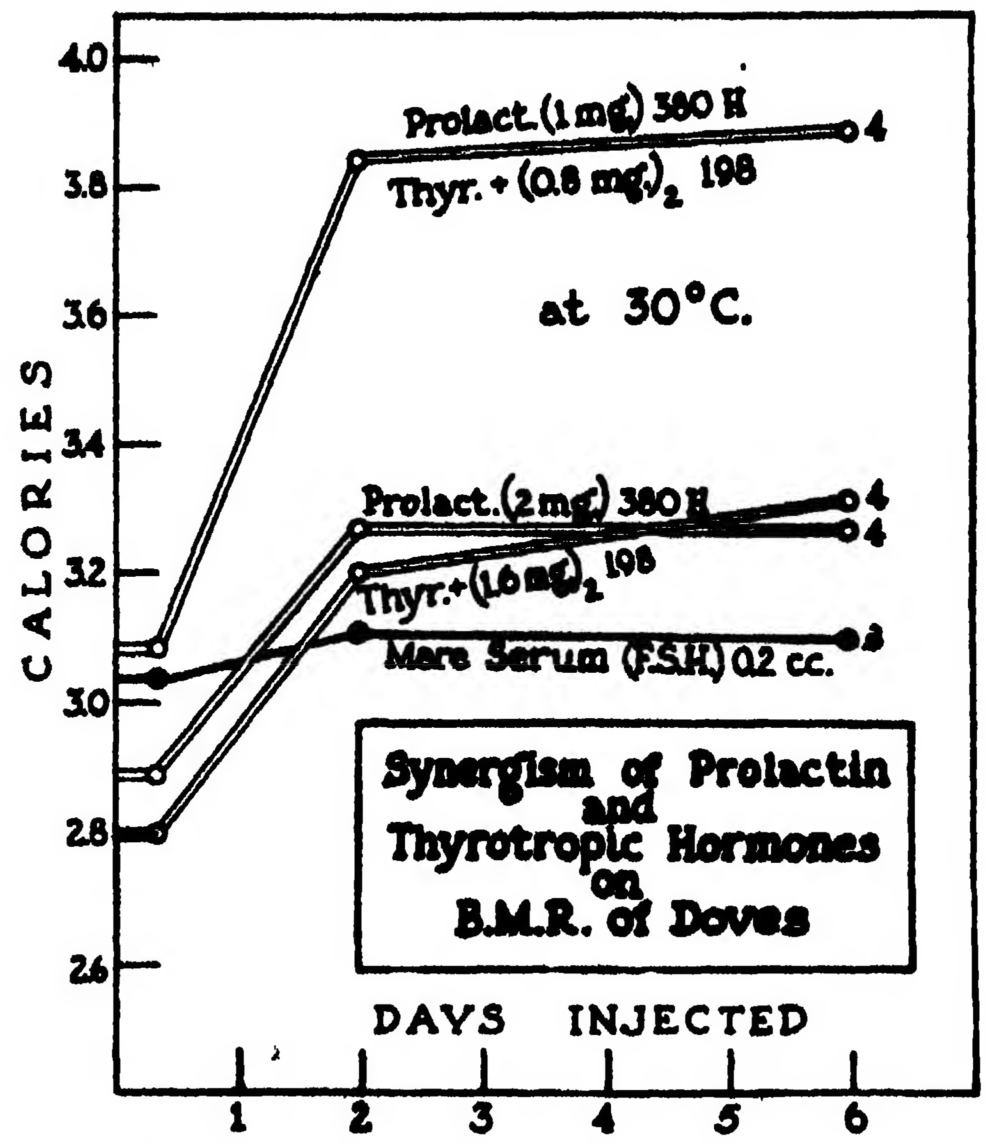


FIG. 3. PROLACTIN ALONE OR THYROTROPIN ALONE INJECTED DAILY FOR 2–6 DAYS INTO GROUPS (4 EACH) OF RING DOVES INCREASES THEIR RATE OF HEAT PRODUCTION. STILL SMALLER QUANTITIES OF THE TWO HORMONES INJECTED TOGETHER PRODUCES A MUCH GREATER INCREASE IN RATE OF HEAT PRODUCTION. SERUM FROM PREGNANT MARES—LACKING THESE TWO HORMONES BUT RICH IN FSH AND LH—HAS NO SIMILAR EFFECT.

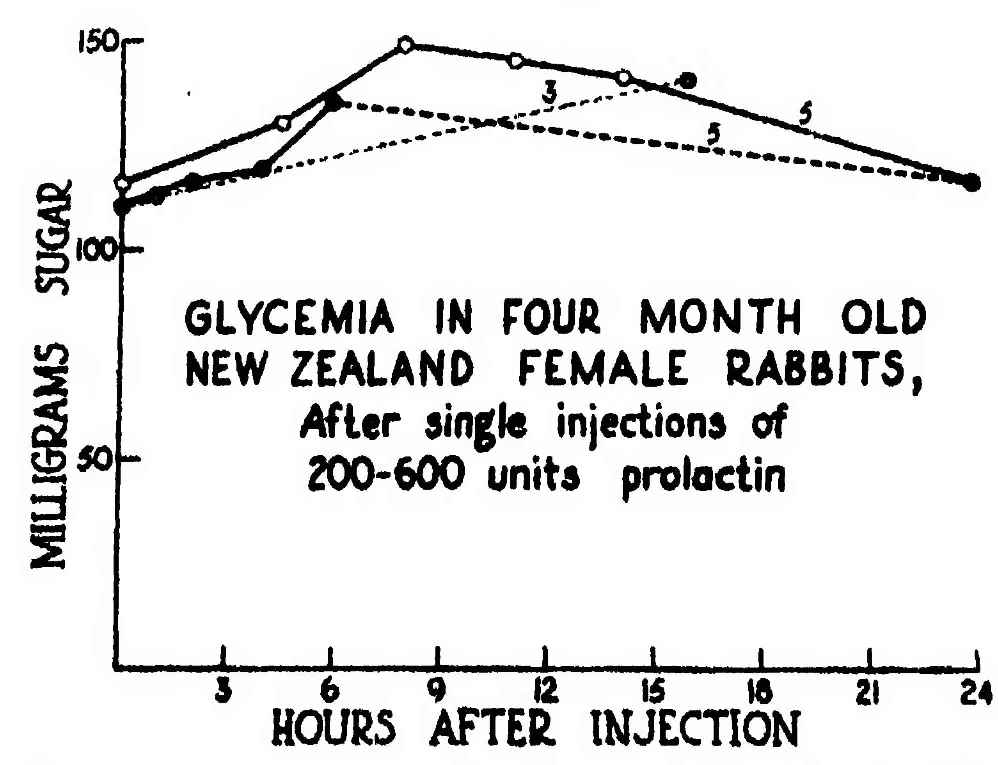


FIG. 4. A SINGLE INJECTION OF PROLACTIN INTO NON-FASTING RABBITS (GROUPS OF 3, 5, 5) CAUSES NO INCREASE IN THEIR BLOOD SUGAR DURING THE NEXT 3 HOURS. THEY DO SHOW MORE THAN NORMAL QUANTITIES OF SUGAR IN THEIR BLOOD AT 7–18 HOURS AFTER INJECTION.

of normal and hypophysectomized pigeons though it does seem to increase the ability of prolactin to form glycogen in

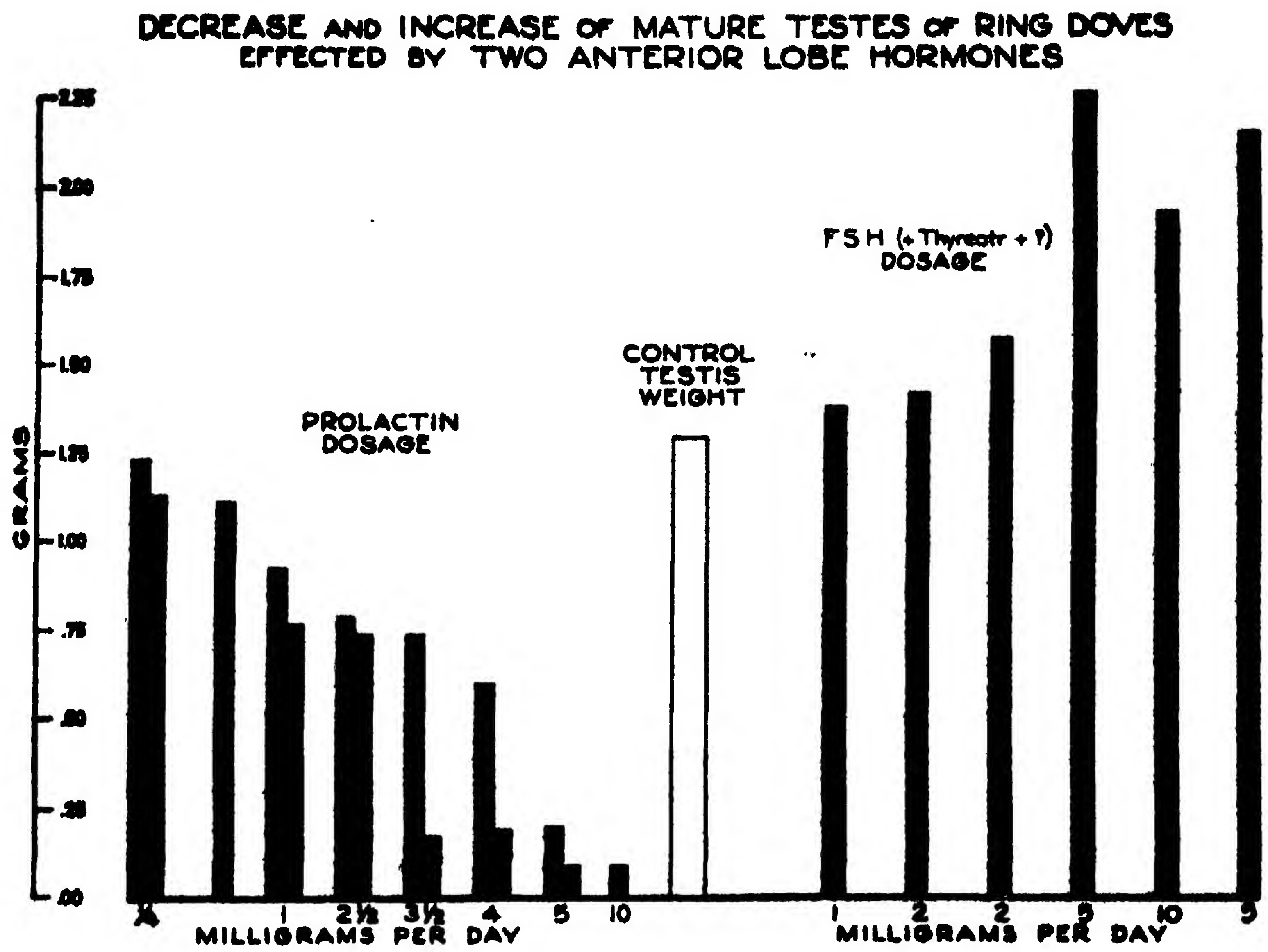


FIG. 5. THE TESTES OF MATURE BIRDS ATTAIN SUPERNORMAL WEIGHT AFTER TREATMENT FOR 7–10 DAYS WITH FSH. PROLACTIN HAS AN OPPOSITE EFFECT THROUGH ITS ABILITY TO PREVENT THE RELEASE OF FSH FROM THE PITUITARY OF THE BIRD THUS INJECTED. HEAVIER DOSAGE AND MORE POTENT HORMONE PREPARATIONS SHOWED THE GREATER EFFECTS ON TESTIS WEIGHT.

the liver. It seems clear that thyrotropin and gonad-stimulating hormones do not have glycemic and glycogen-storing effects similar to those of prolactin although a very few preparations which were rich in these hormones and quite free from prolactin have also shown marked power to increase the blood sugar of pigeons. These exceptional results nevertheless suggest that more than one pituitary product is directly or indirectly concerned in increasing the quantity of sugar in the blood. Whole or undivided extracts of anterior pituitary — and doubtless containing all the hormones of this gland—have usually elevated the blood sugar to a somewhat greater extent than does prolactin alone. It is therefore probable that more than one pituitary hormone shares in this ability to increase the blood sugar, and it is even possible that this increase is a synergized effect or response. Clearly, however, our purest preparations of prolactin have power to increase the blood sugar of rabbits, doves and pigeons. It is a singular fact that neither prolactin nor a mixture of all anterior pituitary hormones seems able to cause similar increases in the blood sugar of fasting normal rats.

We next consider an action of prolactin that has no definitely known parallel among other pituitary hormones. This marked peculiarity relates to the observed power of an excess of prolactin, when injected into the blood of an animal, to decrease—or in some cases wholly to eliminate—the output of follicle-stimulating hormone (FSH) by the pituitary cells of this animal. When prolactin thus shuts off an animal's current supply of FSH it of course becomes responsible —though indirectly—for a decreased activity and temporary atrophy of the reproductive system of this animal. In this performance we again meet an action of prolactin which is of widespread influence in the organism. Moreover, this action contributes directly to a broader theme of this address since we here seem

to find another part of an automatic mechanism, resident in the pituitary gland, through which periods of high ovarian and reproductive activity are appropriately alternated with phases of low activity.

In Fig. 5 the relative heights of the vertical bars at the right show that the sex glands of normal adult male birds can quickly become of supernormal size—normal size being indicated by the height of the central column—if for 7 to 10 days one daily adds some FSH to their blood. Indeed it is found that the more of this hormone that is added the greater is the excess of weight attained by their testes. On the other hand, when prolactin is added to the blood of such birds their testes quickly diminish in size; and indeed under very high dosage of prolactin it is found that the testes of these birds diminish in size almost to the point of disappearance. Precisely similar effects on the ovaries of pigeons and fowl invariably occur after the injection of these two hormones. We here omit a discussion of the somewhat involved experiments which prove that this action of prolactin is accomplished through its ability to stop the production of gonad-stimulating hormone in the animal's own pituitary.

A response apparently similar to that just described has been observed in female rats. Fig. 6 shows the effect of injections of prolactin on the heat or rut cycles of mature female rats. The ovaries of such rats usually reach a high point in their activity at intervals of about 5 days. High and low points in this ovarian activity are here expressed in the form of short curves. The high points of ovarian activity are otherwise known to reflect either high points in the output, or in an accumulated output, of FSH from the pituitaries of these rats. To several female rats showing these regular ovarian cycles prolactin was

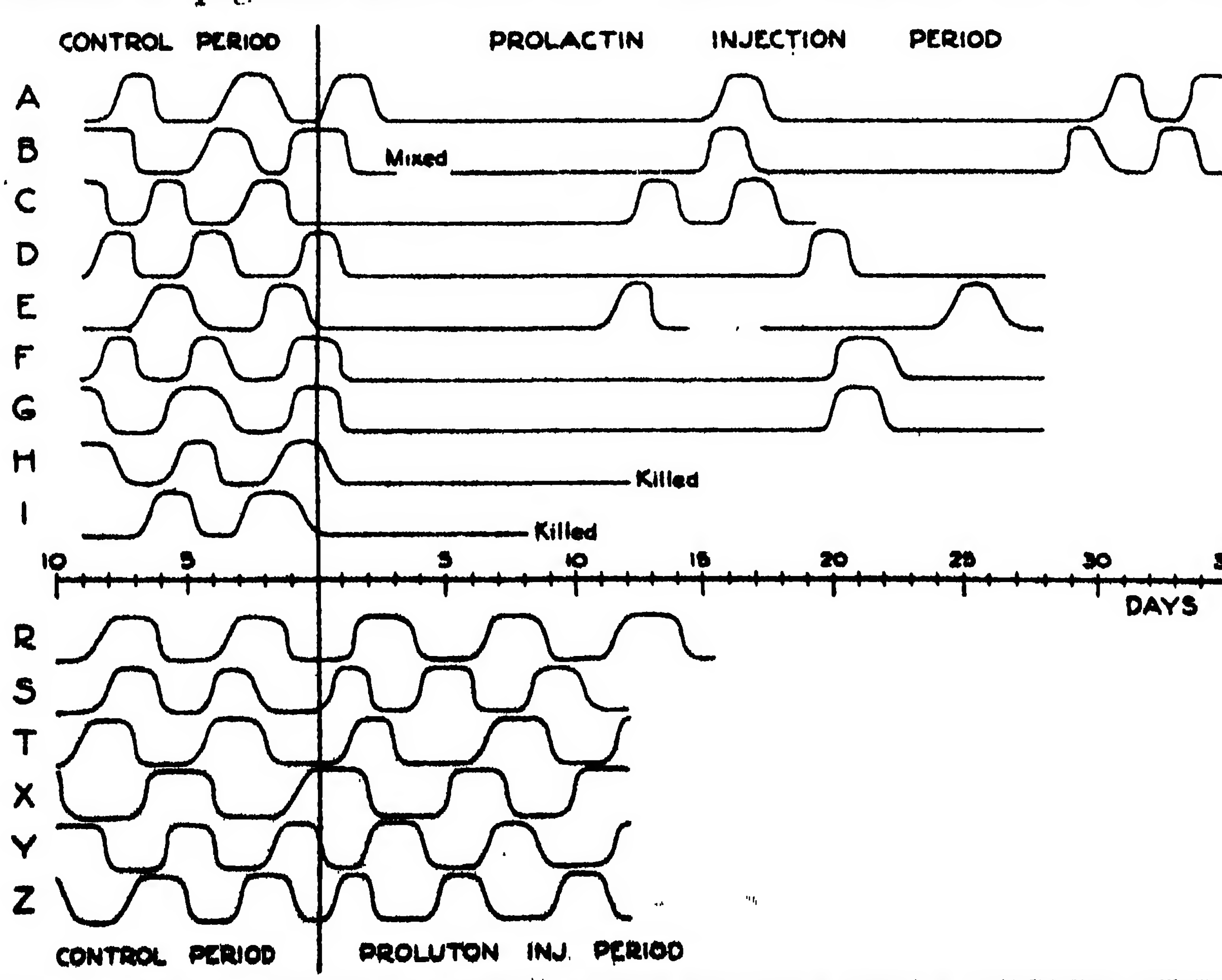


FIG. 6. THE ACTION OF PROLACTIN ON THE HEAT CYCLES OF RATS

THE NORMAL HEAT CYCLES OF 9 MATURE FEMALE RATS (A–I) WERE QUICKLY, THOUGH NOT PERMANENTLY, INTERRUPTED BY DAILY INJECTIONS OF 30 UNITS OF PROLACTIN. THE VERTICAL LINE INDICATES THE POINT AT WHICH PROLACTIN TREATMENT WAS STARTED. THE CYCLES OF 6 RATS (R–Z) GIVEN MODERATE OR LOW DOSAGE OF PROLUTON (PROGESTERONE) WERE NOT INTERRUPTED.

given daily, beginning at the point where the black vertical line crosses the record for each rat. Immediately after beginning treatment with prolactin it is notable that two or more of the next succeeding points of high ovarian activity were absent. At the constant level of prolactin dosage used in our tests ovarian activity was occasionally resumed; but other investigators who have used mice in similar tests have shown that by raising the level

FIG. 7. THE INITIATION OF BROODINESS IN FOWL
MOST WHITE LEGHORN HENS LACK A GENETIC FACTOR FOR "BROODINESS" AND CAN NOT BE MADE WHOLLY BROODY BY PROLACTIN. THIS EXCEPTIONAL LEGHORN HEN WAS MADE BROODY BY 5 DAILY INJECTIONS OF PROLACTIN; THEREAFTER SHE INCUBATED EGGS AND ACCEPTED FULL CARE AND DEFENSE OF 2 DUCKLINGS.

of prolactin dosage these occasional resumptions of ovarian activity can also be suppressed. It should now be emphasized that others have supplied evidence that the luteinizing hormone (LH), rather than prolactin, is responsible for the suppression of these ovarian cycles in rats and mice. Again, we have found that prolactin does not produce atrophy of the testes in male rats. Though these conditions in mammals require further study it seems clear and certain that in birds of both sexes prolactin, not LH, is responsible for the large amount of anti-gonad action observed by us.

Still a third consequence of this ability of prolactin to shut off the supply of FSH can be observed in a rapid decrease of blood calcium in actively reproducing female birds (and practically in this type of animal only). Though this complete story can not be told here its outlines can be quickly stated. In periods of egg production the blood of a bird has double the usual amounts of calcium; and this extra calcium results from the circumstance that the gonad-stimulating hormone which stimulates her ovary to produce eggs likewise induces her ovary to produce extraordinary amounts of the sex hormone "estrin." This estrin acts upon her parathyroid glands and these glands in turn produce more of their hormone—a hormone which mobilizes calcium from her bones or from other sources. But prolactin can stop this whole cycle of events at its source through its ability to check the release of FSH from the bird's own pituitary gland.

We may therefore conclude our examination of three different consequences of an anti-gonad action of prolactin (its ability to restrict output of FSH) with the observation that, under certain restricted conditions, this hormone has been found capable of lowering the calcium of the blood; and, the amount or level of the blood calcium is already known to have significance in several vital processes though its full importance is probably not yet known.

At this point we should consider the rôle of prolactin in the phenomena of broodiness and maternal behavior in animals. These phenomena are of course psychical rather than physical—they involve responses of the brain. It is probable that the ability of prolactin to

induce broodiness and maternal behavior is in part related to the already described anti-gonad action of this hormone; this probability is better supported by the evidence from birds than by that obtained from mammals. Though the precise way in which prolactin thus assists in building an element of consciousness is essentially unknown, it seems to have been established as a fact that this pituitary hormone cooperates with nervous or brain tissue in the building of a mental state. Incidentally, this relationship between a hormone and an element of consciousness is anticipated in the modern view of the nature of the mind. Nowadays, mind is not seen as a thing apart—it is "body-brain" that builds and conserves the phenomena of mind.

The hen which in Fig. 7 seems so full of responsibilities was care-free and steadily laying eggs when she received the first of a series of 5 daily injections of prolactin. By the end of the third day she ceased laying eggs and was clucking. By the fourth day she was broody and sat upon eggs. Thereafter, when two young ducks were offered she accepted them and thereafter fiercely defended them against all human intrusion. Similar results were obtained with other genetically suitable fowl if injections were begun while the birds were actively laying eggs. Otherwise only the clucking response was obtained. Pituitary hormones other than prolactin showed no capacity to induce broodiness in fowl. Moderate or low dosage with a series of other hormones—including the corpus luteum hormone, progesterone—was also ineffective in laying fowl. But in ring doves it has been found that progesterone

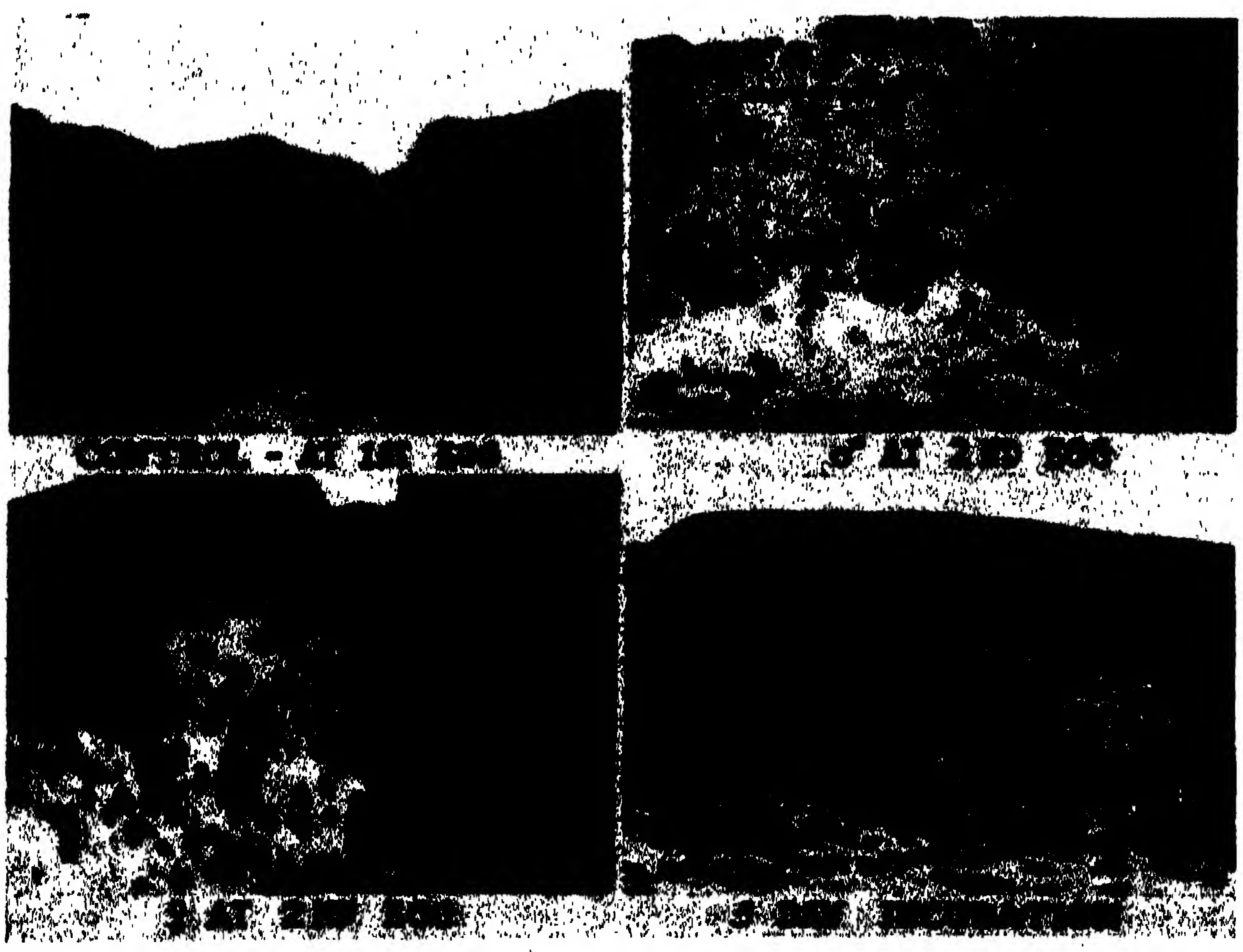


FIG. 8. MITOSES IN THE CROP-WALL OF PIGEONS IN RELATION TO BROODINESS
DIVIDING CELLS ARE LARGE CLEAR CELLS WITH LARGE VERY BLACK NUCLEI—ALL HELD BY COLCHICINE IN A MID-STAGE OF DIVISION. BEFORE BROODINESS BEGINS IN PIGEONS (CONTROL—AT 1ST EGG) FEW OR NO DIVIDING CELLS ARE PRESENT AND THIS SHOWS THAT DETECTABLE AMOUNTS OF PROLACTIN ARE NOT THEN PRESENT IN THE BIRD'S BLOOD. BUT 48 HOURS LATER (♂ AND ♀ AT 2ND EGG) THE BIRDS WERE BROODY AND THEIR CROP-SACS CONTAINED MANY DIVIDING CELLS. IT IS THUS FOUND THAT THE BEGINNING OF BROODY BEHAVIOR IN PIGEONS COINCIDES CLOSELY WITH AN INCREASED RELEASE OF PROLACTIN FROM THE PITUITARY GLAND.

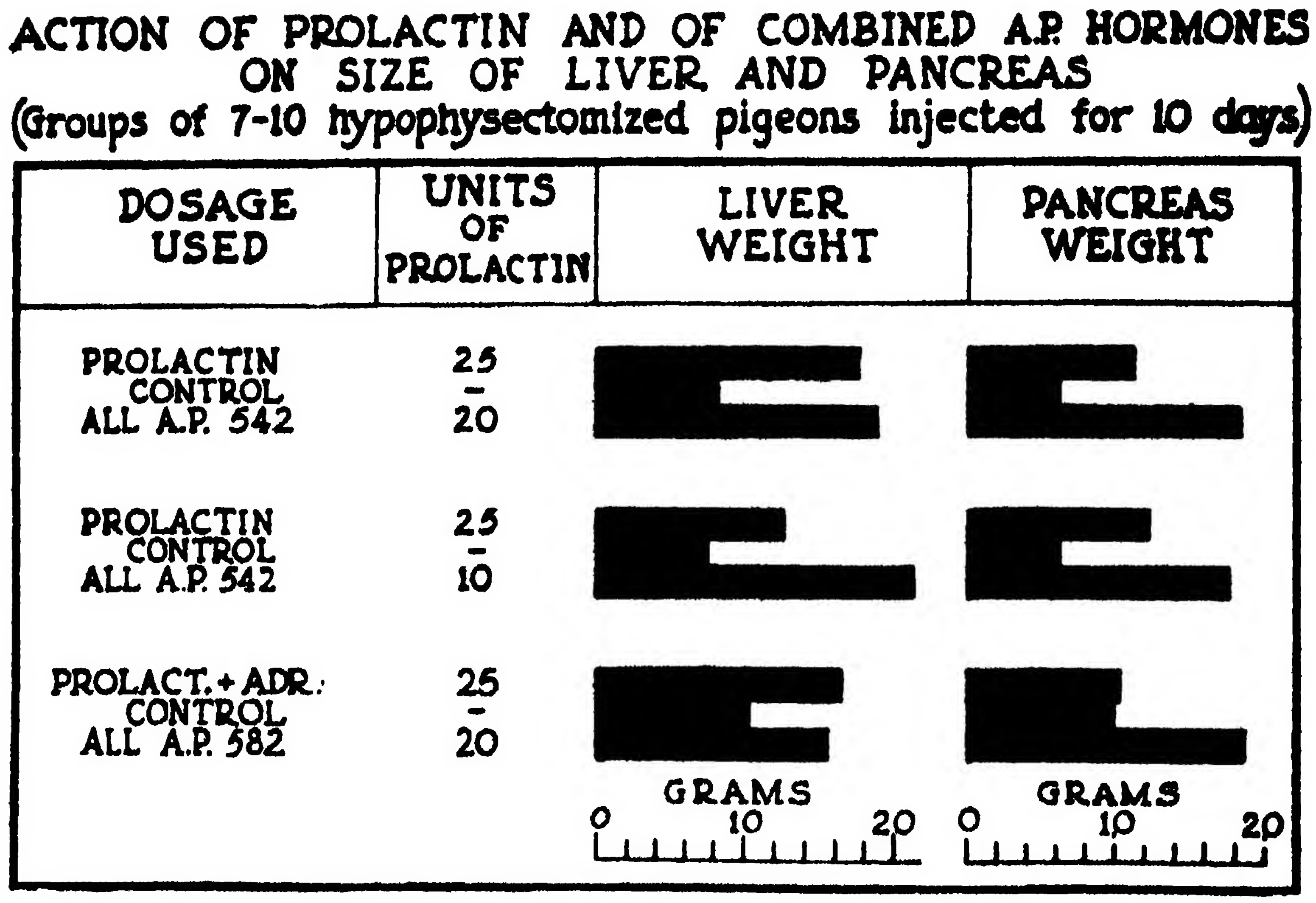


FIG. 9. THE SHORT CENTRAL BLACK SEGMENTS OF THE SEVERAL FIGURES INDICATE THE WEIGHT OF LIVER OR OF PANCREAS IN GROUPS OF UNTREATED (CONTROL) PIGEONS WHOSE BODY WEIGHT HAD DECREASED ABOUT 17 PER CENT. DURING 10 DAYS FOLLOWING THE REMOVAL OF THEIR PITUITARY GLANDS. IN OTHER SIMILAR BIRDS THE WEIGHT OF THE LIVER AND PANCREAS WAS FULLY SUSTAINED BY INJECTIONS OF PROLACTIN DURING THIS 10-DAY PERIOD. WHEN SUCH BIRDS WERE TREATED WITH ALL ANTERIOR PITUITARY (A.P.) HORMONES, INCLUDING PROLACTIN, THE LIVER AND PANCREAS MADE ACTUAL GAINS IN WEIGHT DESPITE THE LOSS OF THEIR PITUITARIES.

can initiate broody behavior in females with active ovaries, also in mature males, though probably not in very young males.

From another angle this same question was studied in the pigeon. It is well known that the behavior of pigeons changes markedly at or immediately after the time their eggs are laid. They may have been quite wild before, but now the brooding bird permits human approach and the handling of eggs beneath its breast. Since the crop-sacs of a pigeon provide the best and surest test for any slight increase in the amount of prolactin circulating in its blood it was highly important to learn whether the onset of incubation in these birds is or is not accompanied by the release of prolactin as this would be shown by a resulting increase of cell divisions in their crop-sacs.

The main result of this inquiry can be observed in Fig. 8. It had first been learned that when we ourselves inject prolactin into a bird an increase in the rate of cell division in the crop wall can be observed as early as 20 to 30 minutes later. Dividing cells of the crop-wall are large cells each with a large central black body—the nucleus. Using the drug colchicine to make each cell division more evident, one finds (in the upper left segment of the figure) few or no cell divisions in the crop-sacs of birds examined on the day on which the first of their two eggs was laid; at that time few cell divisions occur and the birds are not yet broody. The two photographs at upper right and lower left are from crop-sacs taken 48 hours later—and only a few hours after these birds had begun to incubate their eggs. In these cases one finds definitely larger numbers of cell divisions, and this shows that more prolactin was then being produced than in the non-broody period just preceding egg-laying. The photo at the lower right shows conditions in tissues taken after a further period of 5 days—with cells con-

tinuing to divide while broodiness also continues. This crucial evidence therefore indicates that the normal, wholly natural broodiness of pigeons is accompanied by an increased production of the hormone prolactin. And this result rather dramatically strengthens the basis for the conclusion that prolactin normally plays an essential part in the development of the broody instinct in birds.

The action of prolactin and of many other hormones on the maternal behavior of young rats has been studied in a series of more than 1500 tests. Those studies make it clear that certain hormones, particularly FSH and estrin (and prolan) may actually reduce or prevent the exhibition of maternal behavior in these young rats. However, it is found that besides prolactin certain other hormones —notably progesterone, the male hormone (testosterone), and intermedin, and even carbolic acid—also tend to call out this behavior in rats. In the main, it is found that both normal males and females, and castrate males and females, tend to respond or to fail to respond to a particular hormone in about the same way. Again, on a percentage basis prolactin heads the list of hormones and substances capable of developing the maternal or parental instinct, and it is possible that those other substances which exert positive effects do so in part by causing the release of prolactin from the rat's own pituitary. This and still other challenging questions connected with this subject can not be satisfactorily answered

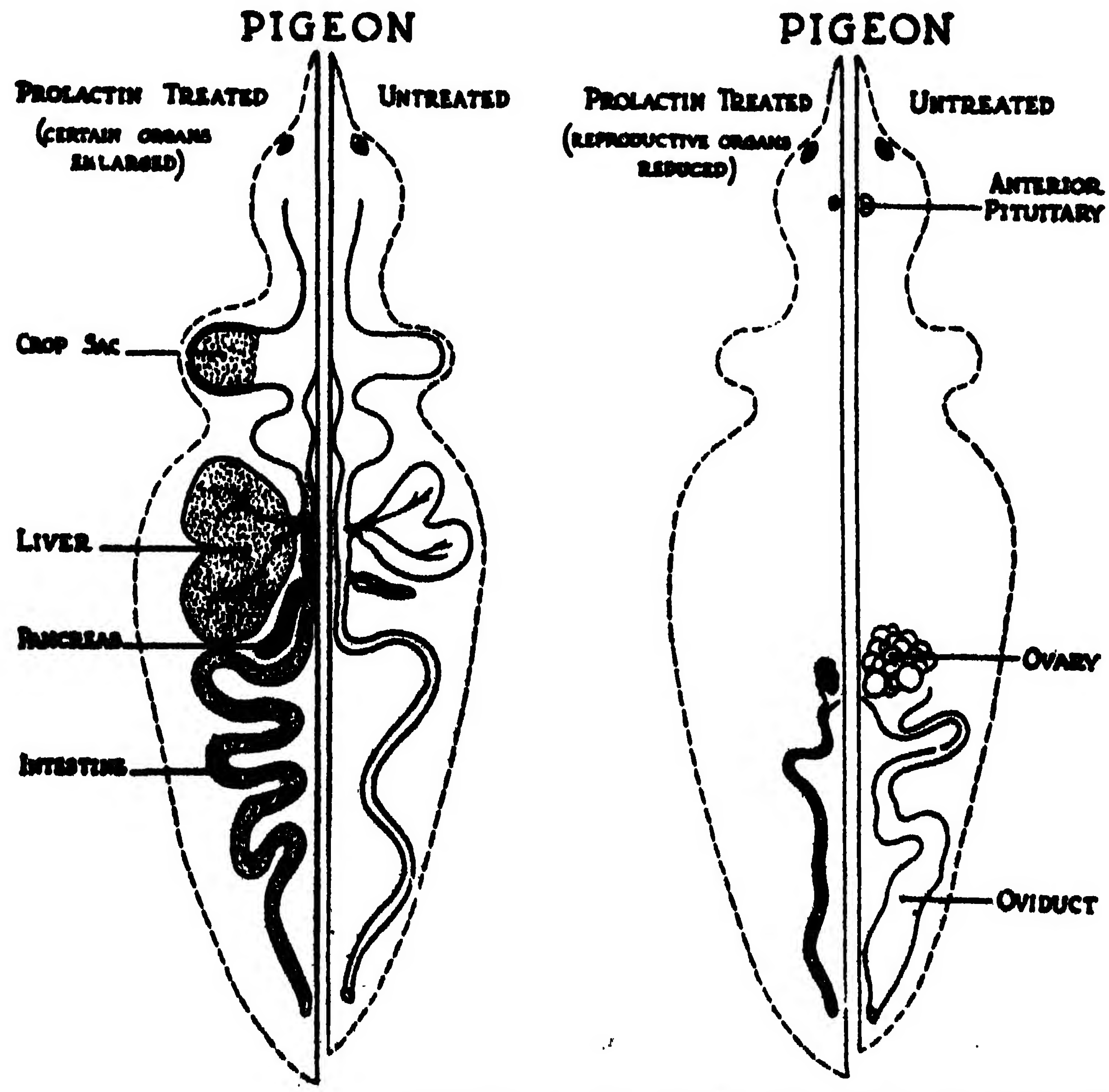


FIG. 10. THE GROSS STRUCTURAL CHANGES INDUCED IN PIGEONS BY PROLACTIN

PROLACTIN INCREASES THE WEIGHT OR SIZE OF THE BODY AS A WHOLE AND IT TENDS TO INDUCE GROWTH IN SEVERAL PARTS OF THE DIGESTIVE APPARATUS—CROP-SACS, LIVER, INTESTINE, PANCREAS. IT DECREASES THE OUTPUT OF FOLLICLE-STIMULATING HORMONE FROM THE PITUITARY GLAND AND IN THIS INDIRECT WAY IT CAUSES A PRONOUNCED ATROPHY OF THE TESTIS, OVARY AND OVIDUCT.

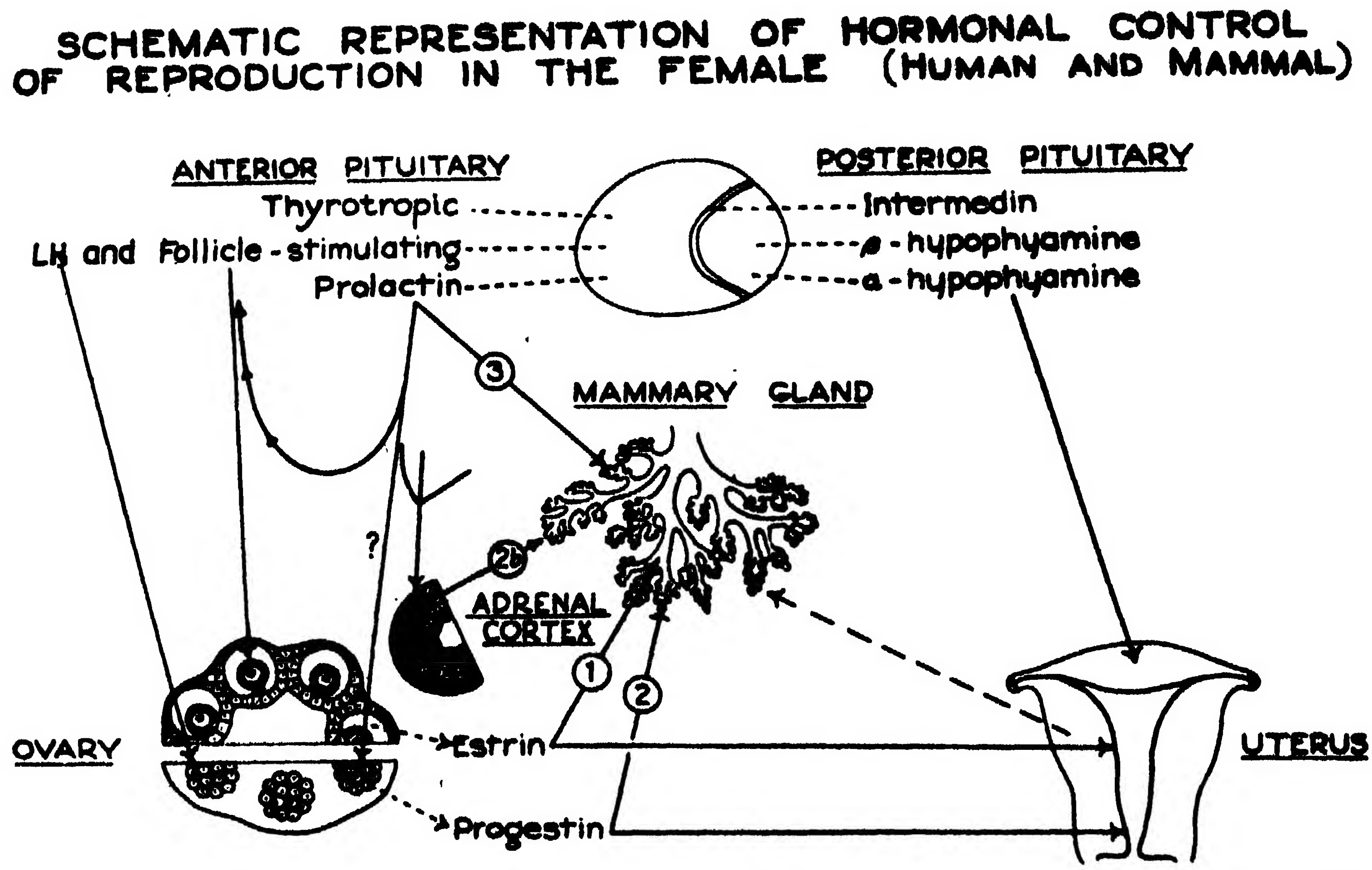


FIG. 11. HORMONAL RELATIONSHIPS AND INTERRELATIONSHIPS INVOLVED IN A COMPLEX MECHANISM (SEE TEXT)

at present and the entire problem is still under active study.

The story of what prolactin does in the animal body will perhaps long remain incomplete; but at present a very significant part of that story seems to be suggested by the now known fact that in pigeons prolactin promotes bodily growth and growth in some important organs—organs mainly associated with the digestive system. Fig. 9 shows—by the length of the ribbons of black—that in birds deprived of their pituitaries prolactin specifically promotes rapid growth in the liver during a 10-day period; and, perhaps indirectly—through increased appetite and food intake after pituitary removal—it also sustains or over-sustains the (intestine and) pancreas. The graph indicates too that prolactin admixed with adrenotropin (ADR.) has probably no greater power to enlarge the liver and sustain the intestine and pancreas than has prolactin alone. In each of the tripartite blocks the lower ribbon represents the amount of growth obtained when presumably all anterior pituitary (A.P.) hormones, including prolactin, were injected together. The results obtained with this mixture suggest that something in addition to prolactin was present and assisted growth, particularly that of the pancreas.

While considering this rapid growth of the liver in pigeons as a result of potent prolactin treatment—its weight may be doubled in 5 days—it should be noted that this growth is accompanied by the deposit of many granules of fat in the liver cells. Moreover, it seems that when adrenotropin is added to the prolactin this deposit of fat in the liver is notably increased. On the other hand, a mixture of thyrotropin and FSH usually seems to have no ability to cause fat to accumulate in liver cells. Practically all that has just been said concerning the hormonal control of the deposit of fat in these liver cells would also apply to the deposit of the carbohydrate, glycogen, in these same cells.

The removal of the pituitary glands

of a large number of pigeons has been found to result in a great loss of appetite and in a marked diminution in the length and empty weight of the bird's intestine. If, however, one begins the injection of prolactin into these birds immediately following pituitary removal their loss of appetite and the atrophy of their intestines are wholly prevented. Indeed, appetite is increased beyond normal, the intestines increase in weight and length, and the bird itself grows instead of losing much weight. Thyrotropin and FSH have no comparable or similar effect upon appetite, intestine, or body growth. Undivided pituitary extracts, containing prolactin and all other pituitary hormones, usually seem to support those several structures and processes somewhat better than does the purified prolactin alone.

The diagrams of Fig. 10 supply a picture of some of the structural changes effected in the bodies of pigeons by a few injections of prolactin. In the pair of half-figures at the left the organs which are either stimulated to growth or have their size markedly sustained by prolactin are indicated by stippling. These several organs are essentially parts of the alimentary system and include the crop-sacs, the intestine, the liver and the pancreas. The size or weight of the body as a whole is increased. In the pigeon, though not in the rat, prolactin is thus seen to be doing just about those things which a "growth" hormone might be expected to do.

The two half-figures at the right depict changes in the reproductive system of the prolactin-injected bird after this hormone cuts off the current supply of FSH from the bird's own pituitary. If it were possible to do so the pituitary of this treated half should be represented as having been affected. The greatly diminished size of the ovary and oviduct of the injected half are shown without exaggerating the degree of their divergence from their former normal state.

Several significant segments of our present knowledge of the hormonal control of reproduction are put together in Fig. 11. The relationships expressed on this diagram have been learned in many laboratories in different parts of the world. This graph first of all reflects the fact that the central control of this complicated system resides in the anterior pituitary, and that the gonad-stimulating hormone (or hormones) is here of primary importance. That hormone carries responsibility for stimulation of both growth and activity in the ovary and testis. As a prime result of such stimulation the ovary begins the production of estrin—the female sex hormone. The estrin then acts at several points. It is here credited with causing growth in both the uterus and mammary gland. And, though this is not included in the diagram, an earlier paragraph has noted some new evidence that estrin may act on the parathyroid gland—inducing the latter to release its own hormone which in turn causes an increase of calcium in the blood. Notable too is the further fact that estrin shares in psychological effects, particularly in those relating to mating behavior.

Of special interest to this whole story are recent observations of others who report that the initiation of the reproductive cycles of some animals—that is, the seasonally increased release of gonad-stimulating hormone from the pituitary gland—is brought about by so simple a means as the increased amount or intensity of light occurring at that season. And again, that this effect of increased light—the renewed secretion of this hormone—is obtained when this light falls on either the eye, or on the cut ends of the optic nerves, or directly upon the pituitary gland itself.

At cyclical intervals the ovary also produces, in its corpus luteum, a second hormone called progesterone. In general, this hormone is produced in cycles or waves which follow similar waves of in-

creased estrin production. Progesterone acts upon the uterus—inducing there such changes in its lining wall as will enable it to attract and anchor a fertilized egg—and it probably also assists the completion of growth in the mammary gland.

Evidence already considered here has indicated that in certain cases prolactin is able to check or halt the production of gonad-stimulating hormone. Such cyclical interruptions of output of this hormone by prolactin would of course bring cyclical depressions of estrin production by the ovary. Our own view concerning the next very complicated phase of this story is that for a longer or shorter period progesterone will continue to be secreted under the same conditions which interrupt and restrict the ovary's production of estrin. It must be further noted, however, that there is much evidence that luteinizing hormone either shares or assumes full responsibility for a sustained production of progesterone in the ovary.

The rôle of prolactin in stimulating the prepared mammary gland to milk secretion is here indicated. Estrin and progesterone were required to develop the mammary tissue; and, for the initiation or maintenance of milk secretion by this tissue—or perhaps for the adequate supply of precursors of milk in the blood—it is probable that the cortex of the adrenal gland supplies a further necessary product. Finally, it is here indicated that a posterior lobe hormone, which has most extraordinary power to cause uterine muscle to contract, may share in the task of completely emptying the uterus at birth.

III

The quite modern elucidation of the endocrine control of the mysterious mechanisms of reproduction constitutes one of the most significant things that man has learned concerning his own existence. These highly complicated and closely interrelated mechanisms have seemed rather obviously beyond the range of control by nerves and brain. They are so eminently adaptive in nature, they involve such cycles of whirling adjustment in the individual life, and they are so basic to the perpetuation of the species, that some biologists and many others have been tempted to suppose that, though naturalism rules in many compartments of the living world, precisely here is a sphere for vitalism—for an unevolved or supernatural force. The foundations for such conjectures have been shaken and dislodged by hard won disclosures of the laboratories—by the patient uncovering of a hormonal basis for interconnected mechanisms which hitherto seemed complicated beyond our comprehension.

Very impressive too is the fact that the later, fuller growth of the bodies of higher animals and man is under the primary control of the anterior pituitary gland. It has been observed that prolactin and thyrotropin synergize body growth in the dwarf mouse. Very important in this general question is the observation that prolactin alone seems to have proved itself capable of causing good growth, along with increased appetite, in pigeons and doves; also that, in these species, the use of thyrotropin, free from prolactin not only does not make them grow but usually results in rather marked loss of body weight. Again, it is evident that gonad-stimulating hormone directly induces growth in the sex glands; indirectly, through the hormones of the sex glands, it causes further growth throughout the reproductive system, modifies secondary sex characters generally and probably affects still other bodily functions. These and other facts lead us to the view that most or all of the products of the anterior pituitary promote bodily growth not only locally but in one or another species—and this largely through their ability to rouse appetite and to keep

vital organs such as thyroids, adrenals, pancreas, liver and intestines in favorable functional states. Personally I am also impressed with evidence that a particular hormone or combination of hormones that is most favorable to body growth in one species is not the combination most favorable to body growth in another species or perhaps in another individual. In short, to us it seems that the growth response to a particular hormone is also modified or limited by a constitutional factor. These views, however, are contrary to hitherto prevailing opinion which credits the anterior pituitary with the production of a single specific "growth" hormone capable of promoting and prolonging bodily growth. Whatever the outcome of the still unsolved problems concerning the precise way or ways in which the pituitary guides and controls our growth it has already been made clear that in some animals prolactin does promote, and in other species thus far tested it does not equally promote, the important processes resulting in bodily growth.

IV

But this discussion ends. In rather more than one sense the anterior pituitary gland is a close and warm associate of the brain. It too is General Headquarters for a diversified system of structures and products dedicated to the great task of regulating and integrating many complicated processes of the living body. From its site there at the very base of the brain it releases to the blood at least three hormones which are essential to the now known story of what the single product—prolactin—does. First, gonad-stimulating hormone which supplies driving power to the growth and functioning of the reproductive system; albeit this product of the basophilic cells can sometimes be stopped or frozen at its source by prolactin—a product of neighboring eosinophilic cells. With the onset of this particular effect of prolactin one may figuratively say that from this small island at the base of the brain the chill of atrophy and inaction spreads to the reproductive organs throughout the body. Second, from this bit of pituitary tissue there is also formed thyrotropin which, in certain cases at least, reinforces and synergizes the action of prolactin on such processes as heat production and bodily growth. Third, prolactin. To the touch of prolactin itself one further observes that such organs as liver, intestine, cropsac and mammary gland quickly respond by growth or by secretion; also that, though several hormones may influence the disposition of protein, sugar, glycogen and fat, prolactin is probably one of these effective agents; and finally that this hormone shares in building the broody or maternal instinct—thus forming one link of a chain that binds body and brain together.

WHAT IS GRAVITATION?[1]

By Dr. PAUL R. HEYL

PHYSICIST, NATIONAL BUREAU OF STANDARDS

LET it be said at the outset that it is no more possible to-day to answer the question "What is gravitation?" than it is possible to answer the similar question, "What is electricity?" Nevertheless, it may be interesting and profitable to set forth what is known about this mysterious and omnipresent force and to review some of the many attempts that have been made to explain it.

A scientific hypothesis, to be acceptable, must take account of both positive and negative evidence relating to the phenomenon which it attempts to explain; that is, the hypothesis must not only account for everything which is observed to take place, but must also be careful not to indicate the presence of anything which is known to be absent. The latter task is the more difficult of the two, and since in the case of gravitation there is much more negative than positive evidence the explanation of this phenomenon is particularly difficult.

What are the known facts about gravitation?

First, as to the mathematical law which gravitation follows. In common with other phenomena in three-dimensional space (light, sound, radiant heat, electrical and magnetic forces) the intensity of gravitation varies inversely as the square of the distance. Since this law is common to so many different phenomena it can not be regarded as characteristic of any, and is not likely to afford a clew to their different natures. As is easily seen to be the case in sound, so with the others; the inverse square law must be regarded merely as the expression of the geometrical fact that the area of a sphere is proportional to the square of its radius.

The best evidence for this law is astronomical, because of the great length of time available for cumulative observation. A very small departure from this law would make itself evident in the motion of the planets after a century or two, and yet only once since Newton stated this law has its accuracy been seriously questioned.

In 1845 Leverrier called attention to the fact that the planet Mercury showed a slight irregularity in its motion, inconsistent with the law of inverse squares and too large to be explained as an error of observation. This discrepancy has been confirmed by later observations, and the seriousness with which it has been generally regarded is shown by the attempts that have been made to explain it on the basis of Newton's law.

All such attempts were failures. It is true that the assumption of a belt of diffuse attracting matter surrounding the sun equatorially might account for this irregularity on the part of Mercury, but such matter, in quantity sufficient to produce this effect, would undoubtedly be visible.

All such attempts having failed, the radical proposal was made to alter slightly the Newtonian law by changing the exponent 2 to 2.000,000,1612. This suggestion was made by Asaph Hall,[2] the discoverer of the satellites of Mars, and for a time it received the favorable consideration of no less an authority than

[1] Publication approved by the director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] *Astronomical Journal*, 14, 1894–95, pp. 49–51.

Newcomb, who abandoned it only after E. W. Brown[3] showed that the motion of the moon would not allow of even this slight departure from the whole number 2. The anomalous motion of Mercury thus remained an unexplained puzzle.

For small distances between the attracting bodies, laboratory experiments with the torsion balance show that the inverse square law holds good for distances as small as ten or fifteen centimeters. The precision of such work is at present about one part in 3000.

The acceleration caused by gravity is the same for all bodies. Newton,[4] by experiments with pendulums of equal length but with bobs of different materials found the time of swing constant to about one part in 1000. Bassel[5] carried the precision of this experiment to one part in 60,000 without finding any positive result. It is worthy of note that among the substances tested by Bessel were meteoric iron and meteoric stone.

The most precise work of this character is that of Eötvös[6] and his collaborators, who by an ingenious modification of the torsion balance succeeded in pushing the precision to six parts in a billion (10^9). The substances tested by them form a considerable list, including copper sulphate both in the solid state and in solution, thus furnishing evidence as to change of state. They also tested a mixture of substances before and after a chemical reaction had taken place between them, and in addition worked with radioactive material. The results were negative in all cases.

The question of a possible effect of temperature on gravitation was investigated by P. E. Shaw.[7] He at first believed that he had obtained a small positive result, which he later found to be due to experimental error. His final conclusion was that gravitation is independent of temperature to two parts in a million per degree Centigrade.

Astronomical evidence on this point is furnished by certain short period comets. As these bodies approach the sun they must arise considerably in temperature, and if this has any effect on gravitation their orbits should be altered considerably. But since these comets return time after time with no displacement other than can be accounted for by the influence of the planets near which they pass, the temperature effect must be non-existent. Because of the great rise of temperature in such cases, many times that which can be applied in laboratory experiments of this character, the precision of this result must exceed that obtained by Shaw.

The possibility that crystals of the non-isotropic systems might exhibit gravitational anisotropy has not gone unrecognized. In the early days of the National Bureau of Standards the suggestion was made that the fundamental standards of mass should be made of quartz. Dr. Stratton, the Bureau's first director, made weighings of quartz crystals in different positions, with negative results. This work was never published. Other investigators,[8] working with quartz and calcite, obtained negative results also.

About fourteen years ago this question was taken up again at the National Bureau of Standards,[9] using large crystals of the order of 1kg, and representing all the five non-isotropic systems. A precision of one part in a billion (10^9) was reached, and the results were negative.

[3] Encyc. Brit., XI edition, article "Gravitation."

[4] Principia, Book III, Prop. VI.

[5] *Annalen der Physik und Chemie*, 25–26, 1832, pp. 401–411.

[6] Eötvös, Pekar and Fekete, *Annalen der Physik*, 68, 1922, pp. 11–66.

[7] Shaw, *Nature*, Apr. 8, 1922, p. 462. *Proc. Roy. Soc.*, 102, Oct. 6, 1922, p. 46.

[8] Mackenzie, *Physical Review*, 2, 1895, p. 321. Poynting and Gray, *Phil. Trans. Roy. Soc.*, A, 192, 1899, p. 245.

[9] Heyl, *Scientific Papers of the Bureau of Standards*, vol. 19, no. 482, Feb. 16, 1924.

Dr. Louis A. Bauer, of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, weighed pieces of steel in a magnetized and an unmagnetized condition with negative results. This work was not published.

The question of a finite speed of travel of gravitative action was discussed by the astronomers of the early nineteenth century, and the conclusion was reached that because of the absence of any perceptible aberration of gravitation its speed of travel, if not infinite, must be many times that of light. There is, however, a tradition that Laplace once started to read a paper on this subject before the French Academy, but after a few sentences stopped, put the paper in his pocket, and saying, "I must consider this farther," left the platform. He probably saw what should have been seen before, that gravitation is not a one-way proposition like light. The earth attracts the sun just as strongly as the sun attracts the earth, and no definite direction can be assigned to the propagation of gravitational action.

But the most characteristic (and possibly the most significant) thing about gravitation is the absence of any screening effect. Many bodies are partially or wholly opaque to light, heat or sound; electric or magnetic forces may be greatly reduced or cut off entirely by interposing a suitable screen, but there is no known screen for gravitation. This can mean only that gravitation, unlike the other phenomena mentioned, is not dependent upon the nature of the intervening medium. In this respect gravitation stands apart from all other physical phenomena save one only, and this one, as we shall see, furnished Einstein with a starting point for his theory of gravitation.

Laboratory work on this point has been carried out, that which has attracted the most attention being that of Majorana.[10] He reported a small positive result which, however, seemed to grow less at every repetition of his experiment. So great are the practical difficulties of such work that a result of the order of magnitude reported by Majorana might easily be accounted for by experimental error.

The best evidence for the absence of gravitational screening is astronomical, and because of the large scale of the phenomena involved and the length of time available for cumulative observation the precision of such evidence is high. For example, one may use the whole earth as a screen and consider what would happen at every eclipse of the moon if there were any gravitational screening. If at such times the solar attraction on the moon should be cut off by an amount as small as that reported by Majorana, the moon would recede slightly from the earth, and this effect would become evident in a few years.

If it be argued that the gravitational shadow of the earth may not reach as far as the light shadow, we may consider the evidence furnished by the tides. The attraction of the moon produces a tide on the side of the earth opposite to the moon as well as on the side facing it, and it has been shown by Russell[11] that an absorption of one five-thousandth of that announced by Majorana would show itself as a perceptible irregularity in the tides.

In this case we have also the evidence of astronomical clocks. Some years ago the Lick Observatory claimed to have found a small difference in the rates of their clocks as between noon and midnight. The records of the U. S. Naval Observatory do not confirm this, results over a period of fifteen years showing no

[10] Majorana, Atti della Reale Accademia dei Lincei, 28, 1919, pp. 160, 221, 313, 416, 480; 29, 1920, pp. 23, 90, 163, 235. *Phil. Mag.*, 39, 1920, p. 488.

[11] Russell, *Astrophysical Journal*, 54, 1921, p. 334. Eddington, *ibid*, 56, 1922, p. 71.

effect as great as one tenth as that claimed by the Lick astronomers. The precision of the Naval Observatory results would limit gravitational absorption to about one hundredth of the amount claimed by Majorana. We may therefore conclude that there is no substance on or in the earth in quantity sufficient to exercise any gravitational screening.

We may now appreciate with what an intractable phenomenon we have to deal. Gravitation appears to be a function of nothing but the masses involved and their space coordinates. As to all other properties, the evidence is negative, in most cases of a high degree of precision, reaching a few parts in a billion. The cause of gravitation is hidden in a protective armor on which there is not even a projection upon which to hang a hypothesis. Yet there have been many guesses at a possible cause, and it may be of interest to review some of these briefly.

The earliest of these speculations that can be ascribed to any definite authority is that of Aristotle. This philosopher was content to explain the falling of bodies by ascribing to them a property of "heaviness," and because he observed that smoke and other vapors rose rather than fell he ascribed to them a property of "lightness," thus dividing all bodies into two classes with a sharp line of distinction between them. The idea that the rising of smoke in air might be a parallel case to the rising of wood in water apparently never occurred to him.

So great was the influence of Aristotle upon human thought that this particular error lasted in the minds of some persons until the eighteenth century. It played an important part in the invention of the balloon by the Montgolfier brothers. These had observed, like Aristotle, the rising of smoke and the floating of clouds, and they reasoned that if they could enclose sufficient smoke in a bag the "lightness" of the smoke would carry the bag upward with it. That they had no thought of the part that hot air might play in this experiment is shown by the fact that the fuel they used for their first fire balloon was chopped straw, a material rather inconveniently bulky, but one which produced much smoke. After the success of their first experiments the true cause of the ascent of their balloon was pointed out by the physicist Charles, who suggested the use of hydrogen in later trials.

Another error was made by Aristotle when he stated that heavy bodies fell with speeds proportional to their weights. Though he might easily have checked this erroneous conclusion by experiment he does not appear to have done so, and so great was his authority that this doctrine was generally accepted by those in authority up to the time of Galileo, in spite of the recorded experiments to the contrary of a number of skeptics, antedating Galileo.[12]

But neither Aristotle nor Galileo nor any intermediate student of Nature seems to have advanced any hypothesis as to the ultimate cause of gravitation. Newton himself, as he says in his "Principia," purposely avoided this; but though he "framed no hypotheses" in his formal and official writings, his letters show that privately he speculated freely, as every scientific man should. There is extant a letter from Newton to Boyle in which it is suggested that the attraction of bodies toward the earth might be due to a change in the density of the ether at different levels above the earth's surface.

Among the many suggestions made since Newton there are a few that it may be of interest to consider. One of the most notable of these is that put forth by Le Sage of Geneva in 1750.

Imagine two circular plates to be held parallel to each other in a hail storm. If the storm is so violent that the stones

[12] Lane Cooper, "Aristotle, Galileo and the Tower of Pisa," Cornell University Press, 1935. Heidel, "The Heroic Age of Science," p. 187. Baltimore, 1933, Williams and Wilkins Co.

may be assumed to come from every direction it will be seen that the two plates will to a certain extent shield each other's inner faces from the impact of the stones, and the closer the plates are to each other the greater will be this shielding. As a result, the two plates will be pushed together by a force which will increase as the distance between the plates is lessened.

Le Sage imagined the universe to be filled with what he called "ultra-mundane corpuscles" flying about in all directions with high speeds, like the molecules of a gas, and pushing together any pieces of matter that happened to be close enough to each other. The obvious objection to this theory is the heating effect of these impacts, and a source of continuous supply for the energy, but it is to be remembered that at the time this hypothesis was put forward the conservation of energy was as yet unrecognized.

Another objection to this theory is that according to it a closed box should at least partially shield particles of matter within it from gravitational action. Gravitational screening, however, was as completely unthought of in the eighteenth century as was the conservation of energy.

We find in Le Sage's hypothesis a concept which has held its own in every later suggestion that has been made as to the cause of gravitation, namely, that gravitation is a push rather than a pull. Lodge,[13] in a lecture entitled, "The Ether and its Functions," makes use of this idea in discussing electrical attraction. He points out that it seems to be a natural tendency of the mind to account for the unknown cause of an attraction by calling it a pull, while in those cases which we have learned to understand we find that it is rather to be described as a push. When a horse, as we say, "pulls" a wagon he really pushes against the horse collar; and when we "pull" a door shut we put our fingers on the other side of the knob and push. The same thing occurs in human relations. When we see some one getting along better than we do, we sometimes superficially account for his success by ascribing it to "pull," while a more intimate acquaintance with the facts will generally show it to be a case of "push."

Le Sage's hypothesis attracted wide attention, and its influence is to be seen in many of the hypotheses which followed it. If we imagine the number of these ultra-mundane corpuscles increased until they pass from the state of a swarm of discrete particles to that of a stream in a fluid, we have the fundamental idea which was repeatedly set forth in one form or another during many succeeding years, and which is still occasionally proposed to-day. The Smithsonian Annual Report for 1876 contains an article by W. B. Taylor, giving a summary and criticism of some twenty-five or thirty hypotheses of this nature. The definite shaping of the concept of the luminiferous ether in the nineteenth century had much to do with the growth and spread of such ideas, but to all such suggestions the non-existence of gravitational screening is a fatal objection. It is conceivable that such streams might penetrate the structure of solids, but not without some reduction in velocity, else the body penetrated would not be subject to gravitation. And any reduction in the momentum of the stream must show itself in a corresponding reduction of gravitative force on the other side of the screen.

A new turn was given this idea that gravitation was due in some way to ether motion when Kelvin[14] in 1867 suggested his famous hypothesis of vortex atoms. When this theory was proposed the question that came at once to the mind of every one was, "Will these atoms gravitate?" It was not at first apparent whether they would or would not, and a

[13] Lodge, *Nature*, Jan. 25, 1883, p. 305.

[14] Kelvin, *Math. and Phys. Papers*, vol. 4.

long and difficult mathematical analysis was required before this question could be answered. Maxwell expressed the hopes and doubts of the time in the article "Atom" which he wrote for the ninth edition of the Encyclopedia Britannica in the 1870's, in which he said, "It may seem hard to say of an infant theory that it is bound to explain gravitation." Such, however, was the case. The searching mathematical examination to which the theory was subjected, largely at the hands of J. J. Thomson, failed to indicate any possibility of mutual attraction between these atoms, and Kelvin finally admitted that his hypothesis must be abandoned.

But hope springs eternal in science as elsewhere, and in a few years a new and promising suggestion appeared. It was discovered experimentally that oscillating or pulsating bodies immersed in a fluid medium such as air or water would under certain circumstances attract each other, and under others repel. At once the question of vibrating atoms in the ether suggested itself. This was given serious study by Karl Pearson[15] in 1889, but he later abandoned this line of attack for another which seemed to him more promising. This was his theory of "ether squirts."[16]

It had been observed that a source in a fluid medium, such as the end of a hose turned on under water, would under certain circumstances attract a similar source. Pearson followed up the hydrodynamics of this problem, and found that not only would two such sources attract each other, but that two sinks, where fluid disappeared, would also attract, while a source and a sink would mutually repel each other.

Pearson suggested that an atom might be a source in the ether at which ether was continually generated, perhaps being poured in from somewhere outside in the fourth dimension, or conversely it might be a sink at which ether disappeared. If the ether was incompressible, as was generally held, and space was full of it, it followed that matter, to exist at all, must be found in equal and opposite quantities of the two kinds. To account for the fact that but one kind is known to us, Pearson suggested that in the course of ages the two kinds had separated by their mutual repulsion, and that somewhere in the distant reaches of space there might be found a universe of the opposite type of matter, a counterpart of our own. Whether this would be of the source or sink variety it was of course impossible to say.

In the discussion evoked by this hypothesis there was cited the instance of a certain star (1830 Groombridge) which possessed the greatest proper motion then known, a velocity so great that it could not have been produced by the attraction of all the known matter in the universe, acting at the distances involved. It was suggested that this velocity might have been produced by repulsion, the star having been at one time much nearer our system.

Against this theory of gravitation there is to be considered the omnipresent objection of gravitational screening, which would entirely vitiate the hydrodynamical reasoning upon which Pearson founded his hypothesis. It is to be said, however, that the full force of the evidence for the absence of gravitational screening was not recognized until the twentieth century.

The next hypothesis of importance came from Osborne Reynolds.[17] In its way it was as original as that of Pearson, for it involved a complete inversion of our ideas of the structure of the universe.

[15] Pearson, *Camb. Phil. Trans.*, 14, 1889, p. 71; *London Math. Soc. Proc.*, 20, 1889, p. 38, 297.

[16] Pearson, "Ether Squirts," *Amer. Journal of Mathematics*, 13, 1891, pp. 309–362.

[17] Reynolds, "The Sub-Mechanics of the Universe," *Sci. Papers*, vol. 3.

Reynolds supposed the ether to have a fine-grained structure such as might result from some process akin to the piling of shot. He further supposed there to be cracks or irregularities in the piling. These empty spaces or cracks in the substratum of the universe Reynolds regarded as the atoms of matter.

He was able to show that under pressure there would be a tendency for two such cracks to approach each other, thus satisfying gravitational requirements. It can be seen, however, that if two cracks were separated by a large completely empty space, corresponding to a thick and very dense piece of matter, while there might be a tendency for both cracks to approach the empty space, the latter would effectually prevent any action of one crack on the other across it. In other words, the objection of gravitational screening again interposes itself.

More theories of gravitation have foundered upon this rock than upon any other. A whole class of hypotheses is ruled out by the screening objection, namely, all electro-magnetic theories.

Every electrical or magnetic action is capable of being screened, partly or wholly, and it is impossible to conceive of any electro-magnetic combination which will not be subject to screening in one or both of its elements. The burden of proof rests upon the author of such a theory to show that the screening objection does not hold. Many such theories have been proposed, suggested probably by the similarity of the inverse square law in each case, but in none of these hypotheses is it specifically pointed out how the screening objection is to be avoided. In fact, one comes from the study of such hypotheses with the impression that their authors either ignore this objection or are ignorant of it.

Thus at the end of the nineteenth century our knowledge of gravitation, in its positive aspect, stood just where Newton had left it. Much experimental work had been done in the hope of showing some relation between gravitation and other physical phenomena, but the results had been all negative. Gravitation seemed to hold itself aloof from other phenomena, steadily refusing to acknowledge any kinship to what were strongly suspected of being its relations. Yet optimism prevailed, and hope was maintained that gravitation would yet be brought into line with other phenomena of Nature.

But like Moses of old, the physicists of the nineteenth century might look ahead over the promised land, but might not enter. It was reserved for Einstein in the twentieth century to make the first positive step toward the correlation of gravitation with other phenomena of Nature. All the facts concerning gravitation were well known to Einstein, who pondered over them, set them in perspective, and by his genius was able to evolve from them a suggestion as to the nature of gravitation which, while not perfect, is the first positive advance that has been made in the subject since the time of Newton.

I have said that gravitation stood for a long time in a class by itself among physical phenomena. In so far as this is true, it was due to the short sight of the observers, for Einstein pointed out that there was another phenomenon of very much the same kind, namely inertia, in the form known as centrifugal force. Centrifugal force is independent of the material, is not a function of the temperature and can not be cut off by any form of screen. In fact, centrifugal force, like gravitation, seems to be a function of nothing but the mass involved and its space and time coordinates.

Einstein illustrates this by means of a revolving disk. Imagine such a disk capable of carrying an observer, such as may be seen in amusement parks. Let the disk be covered by a dome which revolved with it, so that the observer within

can not tell by direct observation of other bodies whether or not the disk is in rotation. Suppose the disk is at first stationary. The observer, in walking from one point to another of his little world, would perceive no difference at the different points; but let the disk be set in rotation, and though the observer could not directly perceive the motion he would become aware of a certain difference. At every point of his space except the center he would experience a force repelling him radially outward, and the greater the distance from the center the greater the force of repulsion. He would, in fact, be in a sort of turned-inside-out gravitational field of force.

With our superior knowledge we recognize this "force" of repulsion to be purely inertial in its nature. As such, it does not originate at the center of the disk, but in the observer himself, and consequently no screen erected between him and the center can diminish the force he feels. Here we have an illustration of how the motion of a system may give rise to something remotely simulating a gravitational field which disappears when the motion of the system stops.

Another illustration that may help us in this connection is that of an elevator. Imagine an elevator with closed walls, containing an observer. Suppose the elevator at first at rest. Let a bullet be fired through it horizontally. The path of the bullet to the observer within will appear as a straight line from wall to wall. If the elevator be moving upward with constant speed, the path will appear as a straight line slanting downward. But if the upward motion of the elevator be accelerated, the path of the bullet will no longer appear straight, but as a curved trajectory, convex upward.

The observer might account for this curved path by saying that the bullet moved according to the resultant of two forces: its original impulse, which would cause by itself a straight path from wall to wall, compounded with another force of attraction of some unknown nature, drawing the bullet downward toward the floor of the elevator. This is assuming a force which does not really exist, and which in consequence may be expected to be rather difficult to explain. What has actually happened is that the observer has changed from fixed to moving coordinates.

Imperfect as are these attempts to represent the actual gravitational field of a body, they may nevertheless help us to understand what Einstein means when he says that a gravitational field is equivalent to an inertial field produced by a suitable change of coordinates; yet neither of these illustrations furnishes us with a change of coordinates adequate to the representation of the actual three-dimensional field of a material particle. The task of finding such a coordinate system, if indeed any should exist, might well appall the best equipped of mathematicians; yet with sublime confidence in his intuition it was to this task that Einstein set himself.

And then a wonderful thing happened, for with but the slenderest of clues, and guided principally by what we may fairly call the intuition of genius, he succeeded! He found a transformation of coordinates which represents a little more accurately than Newton's law the physical phenomena concerned on gravitation.

Imagine a smooth flat frozen surface of a lake. Assuming friction to be absent, a stone set in motion on this surface would move in a straight line with uniform velocity, obeying Newton's first law of motion. If we observed the path of the stone to depart from a straight line at any point we might reasonably infer that there was a slight elevation or depression of the ice at that place. Suppose there to be a large, heavy stone resting upon the ice, producing a rather

deep and widely extended depression or cusp in the surface. At some distance from it, where the ice is again flat, suppose a small stone, which produces no appreciable cusp, is set in motion in such a direction as will carry it past the heavy stone at a short distance from it, well within its cusp. The path of the small stone, at first a straight line, will, as it enters the cusp, gradually assume a curved form. Assuming no attraction to exist between the large and the small stone, the latter will pass on and out of the cusp, its path again becoming straight; but on account of the brief twist to which it was subjected the latter portion of the path will not in general be in the same straight line as the first. The small stone will have suffered a deflection.

An observer watching the motion of the small stone through what we may call Newtonian spectacles, which do not show him the curvature of the ice, will say, "Yes; on passing the large stone the small one seems to have experienced a force of attraction which has deflected it from its straight path." But let him replace these glasses by others of Einsteinian make, and he will say, "No, I see now that there was no force of attraction at all. It was purely the inertia of the small stone combined with the curvature of the surface which it had to traverse that produced the change in its path."

If the small stone passed very close to the large one it might not be able to get out of the cusp at all, but would circulate round and round, describing a curve whose shape would depend on that of the cusp and on the plane of motion of the small stone. If the cusp were shaped somewhat like that around the stem of an apple, the path of the small stone might be an ellipse which failed to close, and would resemble the actual orbit of the planet Mercury.

So much for a two-dimensional surface curved in a third dimension. Einstein's explanation of gravitation contemplates an analogous phenomenon in a space of more than three dimensions. A ray of light coming from a star traverses space for millions of miles remote from material bodies, and consequently "flat." Through this region the path of the ray is a straight line. But if it eventually passes close by the sun, whose great mass causes a considerable cusp or warp in our solid space, the path of the ray becomes twisted, and when it again becomes straight it has been permanently deflected from its original course.

Concepts such as these are apt by their strangeness and transcendental character to cause us to lose the true perspective of the situation. The theory of relativity is but a working mathematical hypothesis, designed to cut a little more closely to the line than that of Newton. But it is still artificial in its nature, and is by no means to be regarded as the ultimate representation of the truth of Nature.

The theory of relativity has done much. It has explained one astronomical phenomenon for which Newton's law of gravitation was found to be inadequate. It has successfully predicted two new physical phenomena. And yet, when it comes to such apparently simple matters as rotational motion and centrifugal force, the theory, as Eddington says, stops explaining phenomena and begins explaining them away.

Einstein himself regards this child of his brain quite sanely. Being a mathematician, he naturally recognizes an empirical equation fitted to a curve as something totally different from the real equation of the curve, and bound to diverge from it if carried out far enough. "No amount of experimentation," Einstein is reported to have said, "can ever prove me right. A single experiment may at any time prove me wrong." Not

that any one has at present a better theory to suggest; but such a thing doubtless will come to pass when the hour and the man arrive. Newton cut so closely to the line that over two centuries elapsed before Einstein could better his formula; and how long it will be before the next corrective term is added to the empirical equation for the great curve of Nature is a matter at present on the knees of the gods.

We have now seen the physical facts, positive and negative, which must be satisfied by any theory of gravitation, and we have reviewed the most important hypotheses which have been proposed to explain these facts. What is the conclusion of the whole matter? Is there anything in all this theorizing that can be considered of permanent importance?

There is at least one concept which, as we have seen, is to be found in practically all gravitational hypotheses from LeSage to Einstein, namely, that gravitation is a push rather than a pull. There is weighty evidence to support this view in the absence of gravitational screening, which must mean that gravitation does not depend in any way upon the nature or condition of the intervening medium, through which a pull would have to be transmitted.

There is also a second idea which may figure largely in future speculation. We have seen it hovering vaguely in the background of Pearson's hypothesis, and have found it faced frankly and stated explicitly by Einstein, namely, that a satisfactory explanation of gravitation transcends the limitations of Euclidean three-dimensional space. Radical as this may seem, it can not be denied that after two centuries of fruitless theorizing the introduction of hyper-geometry brought about the first positive advance in the subject of gravitation since the time of Newton.

The more we study gravitation the more there grows upon us the feeling that there is something peculiarly fundamental about this phenomenon to a degree which is unequaled among other natural phenomena. Its independence of the factors which affect other phenomena, its dependence only upon mass and distance suggests that its roots avoid things superficial, and go down deep into the unseen, to the very essence of matter and the space in which it lives and moves and has its being.

GROUP THEORY IN THE HISTORY OF MATHEMATICS

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It is well known that the ancient Babylonians theoretically used the same symbol for every number of a geometric progression whose common ratio is 60. In particular, they theoretically used the same symbol for every number contained in the infinite series

$$\ldots \frac{1}{216000} \frac{1}{3600} \frac{1}{60} \; 1, 60, 3600, 216000, \ldots$$

As this particular series constitutes an infinite group with respect to multiplication it results that their wedge number symbol, which also represented unity, is the oldest known symbol which was used for a long time to represent an infinite group. Hence this particular group may be said to constitute the basis of their numerical notation. The infinite series of numbers which were constructed similarly by multiplying the terms of this series by the positive integers from 2 to 59 inclusive obviously do not separately constitute a group with respect to multiplication, since they do not include unity.

There has been a tendency in the development of mathematics towards greater and greater generality, but the numerical notation of the ancient Babylonians is a striking exception to this fundamental tendency. This numerical notation, which is also practically a positional number system to the base 60, is unique in the history of mathematics. The use of the same number symbol for every term of a geometric progression of numbers is so different from our common modern system in which two distinct numbers are always represented by distinct symbols that it is quite difficult at first to understand why a people who had made so much progress in civilization could be satisfied with a numerical system which seems to have such obvious disadvantages. One of its advantages is that it practically makes the use of common fractions unnecessary, and these were somewhat troublesome in early civilizations.

While the ancient Babylonians used in their common number system the group formed by the terms of a geometric progression which has unity for one of its terms they did not use in this system the more important group formed by the totality of the positive rational numbers. In particular, the unit fractions 1/2, 1/3, 1/4, 1/5, 1/6 were represented in this system by 30, 20, 15, 12, 10, respectively, but the fraction 1/7 did not form a regular number of this system. Their regular unit fractions had no prime factor in their denominators besides 2, 3 and 5. While their number system had many practical advantages in an early stage of civilization it would not be acceptable at the present time. One of its great defects was that it did not involve a symbol corresponding to our modern decimal point. Its existence points to the advantages resulting from an emphasis of the property of similarity. In particular, 10 and 10,000 represent the same amount of money if the unit in the former case is a dollar and in the latter a mill.

In the introduction to his widely used "Theorie der Gruppen von endlicher Ordnung," third edition, 1937, A. Speiser emphasizes the fact that regular geometric figures may have been studied by group theory methods as early as 1500

B.C., and that Egyptian ornaments may have been the objects of mathematical study in ancient times. It is clear that some of these ornaments can not be fully comprehended without a study of the related groups of transformations, but the evidences pointing to the existence of an early group theory among the Egyptians are not yet entirely conclusive. It should also be noted that the fact that the Babylonians actually used an infinite group as a basis of their numerical notation in very ancient times does not prove that they were then interested in the study of group properties. The existence of this group at that time and of a symbol for it are, however, well established.

The group formed by the positive rational numbers when they are combined by multiplication was probably the most potent factor in making the group concept commonplace at the time when Euclid's "Elements" were written so that it did not seem necessary to emphasize this concept in these "Elements." The study of the regular geometric figures by the ancient Greeks presented many opportunities to direct attention to group properties which were not then utilized. In fact, the first figure in Euclid's "Elements" relates to the regular triangle, but its group of movements is not mentioned in connection therewith. This omission may have been largely due to the fact that it was not then known that the subject of group theory has such wide contacts and hence it is now desirable to emphasize its elements whenever a proper occasion presents itself.

In 1898 H. Poincaré published an article in the *Monist* in which he used the following words:

> The principal foundation of Euclid's demonstrations is really the existence of the group and its properties. Unquestionably he appeals to other axioms which it is more difficult to refer to the notion of group. An axiom of this kind is that which some geometers employ when they define a straight line as the shortest distance between two points. But it is precisely such axioms that Euclid enunciates. The others, which are more directly associated with the idea of displacement and with the idea of groups, are the very ones which he implicitly admits and which he does not deem necessary to enunciate. This is tantamount to saying that the former are the fruit of later experience, that the others were first assimilated by us, and that consequently the notion of group existed prior to all others.

Although the group concept had become commonplace at the time of Euclid it took about two thousand years longer to start a vigorous development of this concept and to move it gradually into the foreground of mathematical investigation. This forward movement was started during the latter half of the eighteenth century by various writers, including J. L. Lagrange (1736–1813), who stated explicitly that the order of every substitution group on n letters divides the order of the symmetric group on these letters. He also called attention to various special substitution groups, including the now well-known non-cyclic group of order 4, which has been called recently "Kleinsche Vierergruppe" by various German writers in honor of the outstanding German mathematician, Felix Klein (1849–1925), who used it extensively under its now common German name "Vierergruppe."

To illustrate the fact that honors are sometimes bestowed in a questionable manner in the history of mathematics it may be of interest to mention here some additional facts relating to the name "Kleinsche Vierergruppe." This group, composed of four elements, is the simplest non-cyclic group, and it is represented by the four movements of our ordinary space which transform into itself a given fixed rectangle having two unequal sides. It therefore seems likely that its properties were observed in ancient times already, but it is not now

known when these properties were first recorded. As was noted above they appear explicitly in an article by J. L. Lagrange published in about 1770, which became well known soon thereafter. They appear also in at least one other widely known work, which was published before Felix Klein was born, *viz.*, in the "Exercices d'analyse" of A. L. Cauchy, volume 3, page 252 (1844).

It is, however, more important in this connection to note the fact that this particular group was widely used and explained during the early years of Felix Klein, before he began to publish anything on this subject. In particular, when he was about five years old, the noted English mathematician A. Cayley (1821–1895) published an article in the *Philosophical Magazine* (1854) in which he gave a detailed multiplication table of this group and explained again its properties. It is therefore well established that when Felix Klein began to use this group its abstract properties were widely known. This makes the fact that it is now so often referred to as the "Kleinsche Vierergruppe" more interesting as a historical fact, since it throws light on the significance which should be attached to the naming of things in science in honor of an outstanding man.

Very few groups have as yet received special names. These include the octic group, which is the dihedral group of order eight and corresponds to the dihedral group of order four, which was noted above. Notwithstanding its great simplicity, this group apears under five entries in the second edition of "Webster's New International Dictionary," as follows: "anharmonic group," "axial group," "cross-ratio group," "four-group" and "quadratic group." In Bôcher's "Introduction to Higher Algebra" (1927), it is called the "fours group" as a translation of its German name "Vierergruppe." Since there are two abstract groups of order four and five abstract groups of order eight the terms "four group" and "octic group" fail in themselves to give characteristic information in regard to these groups. We are, however, not so much interested in this connection in the feasibility of giving individual names to individual groups as in the question of the historical significance of assigning names in honor of an individual and in the historical tendency to centralize credits unduly.

During the long period of time extending from the ancient Babylonians to the latter half of the eighteenth century the concept of group entered very gradually into mathematical thinking, and it did not then even receive a special name. Such a name was given to it by J. L. Lagrange in the article to which we referred, but this concept did not attain maturity until a satisfactory definition of an abstract group appeared more than a century later. The word group is an instance of the adoption of a common word by mathematicians to represent a concept which grew rapidly thereafter and became so complex that its definition could not be inferred from the common meaning of its name. Even in the subject itself the common meaning of the terms are often misleading, since the term simple groups is used to represent the most difficult category of groups. When the youthful E. Galois (1811–1832) introduced the word group as a technical term he could not foresee the enormous amount of literature which has since then appeared under this word and is still appearing thereunder.

When E. Galois died he is said to have expressed regrets that he could not have died for his country. The glory which his work on groups has brought to his country through the efforts of thousands who proceeded along lines to which he first called attention seems to be a greater

credit to his country than his death in fighting in her behalf could have been. The facts that his work at first failed to receive due recognition and that he endured many hardships in consequence thereof may have led to a deeper and more sympathetic interest in his work on the part of some of those who later understood its real significance. At any rate, E. Galois has been a very inspiring figure in group theory as well as in the general history of mathematics. Additional evidence along this line was recently furnished by an American publication, entitled "Galois and the Theory of Groups, a Bright Star in Mathesis," 1932. Many mathematicians have expressed surprise because his name does not appear in the "biographical dictionary" of "Webster's New International Dictionary," 1935.

As evidence of the influence of the concrete in the development of modern mathematics it may be interesting to note here that during the first hundred years from the time of J. L. Lagrange's work along this line group theory was developed mainly as a concrete subject, with gradually increasing emphasis on its abstract properties. The permutations or substitutions which were the main objects of group theoretic study during this period are partly abstract, since they do not concern the nature of the objects which are permuted just as one foot does not specify the object measured. It is, however, customary to class one foot with concrete numbers. An occasional movement towards abstract group theory appeared about the middle of the nineteenth century, especially in the work of the English mathematician, A. Cayley, but this movement was not placed on a solid foundation before the appearance of a satisfactory definition of the term abstract group in 1882. Group theory thus furnishes an interesting modern example of the movement from concrete to abstract ideas in the development of mathematics.

THE HISTORY OF THE LICK OBSERVATORY

By Professor CHARLES H. SMILEY
DIRECTOR OF THE LADD OBSERVATORY, BROWN UNIVERSITY

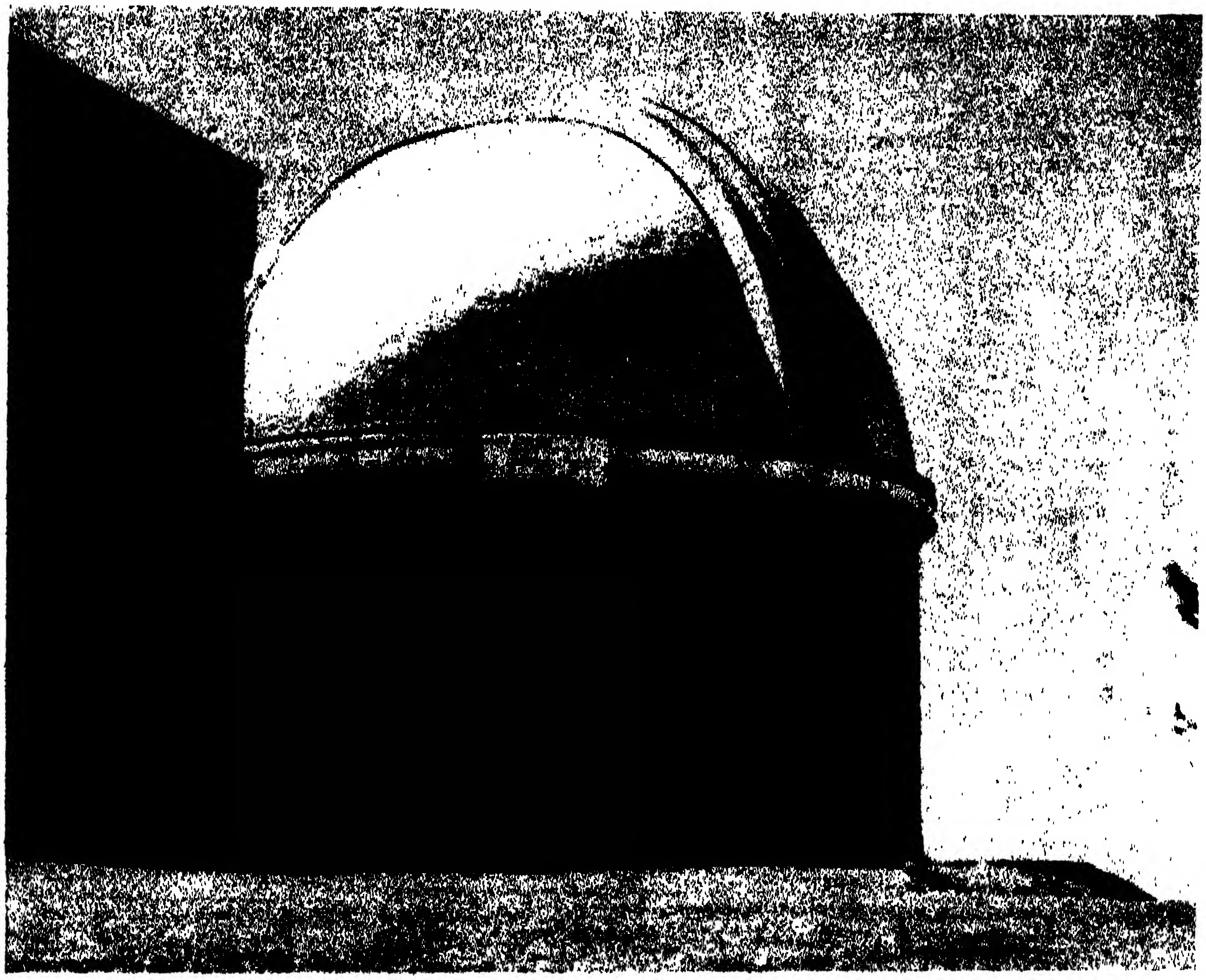
THE Lick Observatory of the University of California was founded through the generosity of James Lick, an eccentric California millionaire. He provided $700,000 for the purchase of land, the construction of buildings and the construction of "a powerful telescope superior to and more powerful than any telescope ever yet made, with all the machinery appertaining thereto and appropriately connected therewith, or that is necessary and convenient to the most powerful telescope now in use, or suited to one more powerful than any yet constructed." No one knows why James Lick decided to provide the money for this observatory. So far as is known, he had never looked through a telescope. Somewhat later, in his "Reminiscences of an Astronomer," Simon Newcomb said that if Lick had looked through a telescope, Lick Observatory probably would never have existed. Lick was apparently a difficult person with whom to get along. He took a dislike to a member of the first board of trustees, and as a result the entire board resigned. A second board was named, and yet again a third, before Lick died and the observatory was finally constructed.

Lick placed several restrictions on the use of his money. One was that the observatory should be erected in California. Another was that he should be buried in the pier which supported the great telescope. If he could clearly have foreseen the future, he probably would not have made the latter provision. In 1927, when the author of this article first went to Lick Observatory, as a graduate student of the University of California, he accompanied another graduate student one evening to the dome of the 36-inch refractor. After a short time in the quiet dark dome, an eerie sound was heard and he called to his friend, "What on earth is that?" "Oh," the friend laughingly replied, "that is just James turning over in his grave." In reality, it was due to a part of the mechanism of the telescope.

In the beginning, Lick wanted the telescope mounted near the edge of Lake Tahoe, but this site was abandoned because of the severe winters in that region. A number of sites, including Mt. St. Helena, Mt. Diablo, Loma Prieta and Mt. Hamilton, were considered before the final decision was made. S. W. Burnham spent two months on Mt. Hamilton in the fall of 1879, observing many double stars with a six-inch telescope before he reported that this would be a satisfactory location for the Lick telescope. This favorable report came as a surprise to Newcomb and other astronomers who had thought that rising currents of air would disturb the "seeing" on a mountain peak. This observatory was the first large one to be located on a mountain top; its success is reflected in the locations of the large reflecting telescopes built in recent years, Mt. Wilson, Mt. Locke, Mt. Palomar.

A congressional grant, made on June 7, 1876, provided 1,946 acres for the observatory site. The state of California gave 511 acres, 703 acres were acquired by purchase or gift and 30 acres were sold, leaving a total of 3,130 acres.

On Mt. Hamilton, there were three peaks: Mt. Copernicus, 4,448 feet, Mt. Kepler, 4,318 feet, and Observatory Peak, 4,302 feet. It was necessary to remove 72,000 tons of material from the



THE SEVENTY-FIVE FOOT DOME OF THE THIRTY-SIX INCH LICK TELESCOPE, THE SECOND LARGEST REFRACTOR IN THE WORLD.

last-mentioned peak to get a level platform large enough for the erection of the main building. Mt. Kepler became the site of the water reservoir, the source of the water being a spring 350 feet below the summit and almost a mile from the observatory. Another spring has since been added to the observatory water supply.

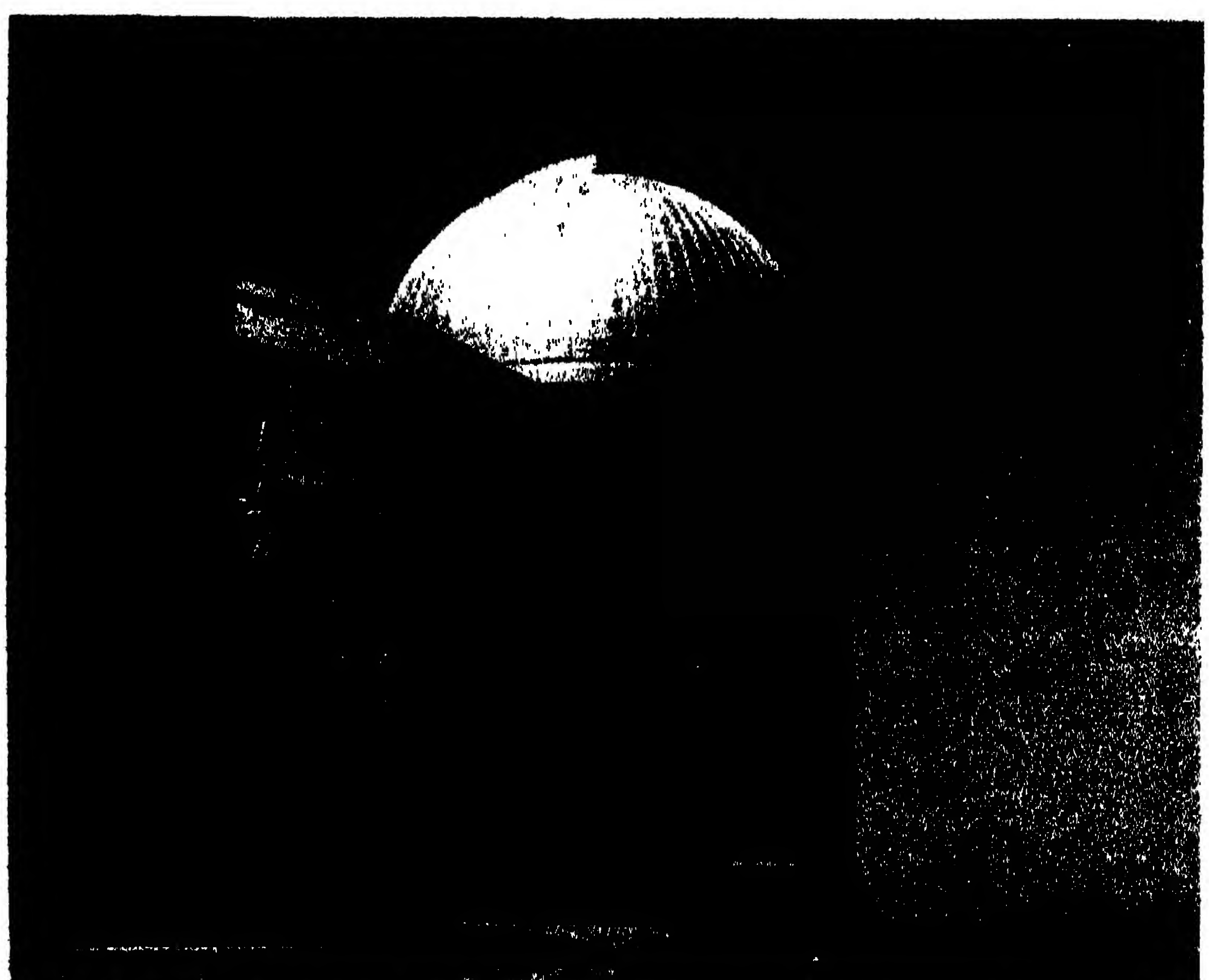
To make the observatory accessible, Santa Clara County completed in December, 1876, a road 22 miles long at a cost of $80,000. This road rises 4,000 feet and at the steepest grade in any part of it, it rises only six feet in a hundred. When one hears that the mountain is only 13 miles by air-line from San Jose and 27 miles by road, one suspects that the road is crooked. In the last seven miles, there are 365 turns, one for each day in the year. Young astronomers working on the mountain have named each of these turns; the very last one before reaching the observatory is called "Oh My" because of the exclamations of visitors as they look out over the precipice into the emptiness of space.

With the coming of the automobile, San Jose was much more accessible to the astronomers. Occasionally on cloudy evenings, some of them drive down to see the movies, returning the same evening. On one occasion, Dr. C. S. Yü, then a graduate student, was driving down the mountain in a small automobile. On one of the turns, the machine turned over, stopping at the very edge of the road. Mr. Yü, uninjured, climbed out to mar-

vel at his narrow escape, then crawled back under his car to get his camera so he could photograph the overturned car. Shortly after that, another machine came along; the occupants helped Yü turn his machine over and watched him drive on down the mountain.

The lens for the large telescope was made by Alvan Clark, after Simon Newcomb, at the request of the trustees, had visited all the leading European glass makers and telescope makers and had reported that the Clark firm was best fitted for the work. He also decided that refractors were most reliable. If Lick had been alive, he would undoubtedly have objected to the awarding of the contract to the Clarks. He had written to Alvan Clark asking how large a telescope might be made and what such a telescope would cost. Without giving the matter careful consideration, Clark had replied, "$200,000." Lick felt that this was much too much and would have nothing more to do with the firm. He did not have a clear idea of the mounting necessary for a large lens. Apparently he felt that a lens hung at the end of a pole would be enough.

After his death, the trustees were free to do things as they felt they should be done. In 1880, the Clarks started work on the large lens. It took seven years to build and cost $50,000, exclusive of the mounting. It was shipped by rail to California in 1886 in a special car with 16 persons accompanying it. Alvan G. Clark went along and stayed on Mt. Hamilton until the lens was in place. For nine years, until the completion of the forty-inch lens of the Yerkes Observatory in October, 1895, it was the largest refracting telescope in the world. Even now, after more than fifty years, it is still the second largest refractor. It was originally planned and constructed for



THE DOME OF THE TWELVE-INCH REFRACTING TELESCOPE OF THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA.

THE DIRECTOR'S RESIDENCE AND THE DOME OF THE THIRTY-SIX INCH CROSSLEY REFLECTOR.

visual work; a 33-inch correcting lens was made by the Clarks to adapt it to photographic work.

The mounting was made by Warner and Swasey. It was the first of the many great instruments mounted by them. This firm was also responsible for the 75-foot dome housing the large telescope and for the 60-foot elevating floor. The latter was a novelty then; it has since been copied in many observatories.

At the recommendation of Simon Newcomb, Edward Singleton Holden, then director of the Washburn Observatory of the University of Wisconsin, was chosen to be the first director of the Lick Observatory. A cousin of George P. Bond, of Harvard College Observatory, and son-in-law of William Chauvenet, he had worked for a time as an assistant to Newcomb at the U. S. Nautical Almanac Office. He was made president of the University of California in 1885, holding this position until 1888, when he resigned to take the post of director of Lick Observatory. At that time, he filed a bill for $12,000 for the advice and assistance he had given the trustees while the observatory was being built. This was entirely unexpected, but the chairman of the board of trustees, a diplomatic soul, upon the advice of Newcomb, suggested to Holden that his purpose in filing the bill undoubtedly was to place on record his valuable services in the erection of the observatory. Holden did not disagree with this statement and did not press for payment.

Much of the brilliance of the history of the Lick Observatory can be credited to the good judgment of Holden in picking the men who were to work under him. S. W. Burnham and J. E. Keeler had already established reputations for themselves, while E. E. Barnard, W. W. Campbell and J. M. Schaeberle were later to become outstanding men in the field of astronomy.

Holden's time was largely taken up with administrative duties; his principal research during his time as director was concerned with the making of a splendid photographic atlas of the moon.

In 1895, Edward Crossley, of Halifax, England, gave a 36-inch reflecting telescope to the Lick Observatory. The mirror was made by Sir Howard Grubb and the mounting by Ainslee A. Common. The costs of transporting it from England and of housing it in California were met by popular subscription.

It had been planned that the astronomers and their families were to live on the mountain top. To this end, a schoolhouse was erected and Santa Clara County provided a teacher for the children. In more recent observatories, this arrangement has not been followed. A community isolated on a mountain-top is essentially a small town, with all its disadvantages and inconveniences. This may explain in part some of the unfortunate animosities which appeared during Holden's term as director; the story in its entirety has never been told. In any case, Holden resigned in 1897, retiring to private life. Later he served as librarian at West Point.

He was followed by James Edward Keeler, who had been serving as director at Allegheny Observatory since 1891. Perhaps Keeler's greatest contribution to Lick Observatory was the preparation of the Crossley reflector for useful work and in showing that it could be used in the study of the extra-galactic nebulae. He showed that these nebulae were numerous and that a large proportion of them were of the spiral type. His relatively peaceful term as director ended with his death in 1900.

Keeler was succeeded by the late William Wallace Campbell, who continued as director of the Lick Observatory until 1930, though he was also president of the University of California from 1923 to 1930. Campbell is probably best known for his application of the spectrograph to the study of stellar motions, a field in which he was a pioneer. Many of the outstanding American astronomers of today served an apprenticeship at Lick Observatory and had a part in the gathering of data on stellar radial velocities. To extend this important work to cover the southern hemisphere as well as the northern, friends of the university provided funds for a 37-inch Cassegrain reflecting telescope equipped with several spectrographs, and the erection and maintenance of a station at Cerro San Cristobal, near Santiago, Chile. This southern expedition, originally planned to last for two years, continued from 1903 to 1929, when the Chile station was sold to the Catholic University of Chile. In this program, more than 25,000 spectrograms were made at Mt. Hamilton and Cerro San Cristobal, from which the radial velocities of 2,771 stars brighter than magnitude 5.51 were determined. The apex of the sun's way as determined from these radial velocities agrees very well with the positions previously determined from the proper motions of stars.

Robert Grant Aitken, known internationally for his work on double stars, followed Campbell as director. He continued in this post to 1935, when he was succeeded by William Hammond Wright. Wright is perhaps best known for his work on the use of color filters in the photography of planets, though his work on the spectra of gaseous nebulae and novae is probably at least as important scientifically. It is interesting to note that in the fifty years of existence of Lick Observatory, there have been only five directors. Two of them have served for a time as president of the University of California, and each of the last three has received the Gold Medal of the Royal Astronomical Society.

In a brief article such as this, one could

RESIDENCES, SCHOOL-HOUSE, WATER RESERVOIRS AND SMALL DOME HOUSING CROCKER SIX-INCH PHOTOGRAPHIC TELESCOPE.

not hope to mention all the important discoveries and studies made at the Lick Observatory, nor indeed all the outstanding astronomers who have been connected with it. The omission of a discovery or of an astronomer, it is hoped, will not be construed as reflecting in any unfavorable way on the discovery or the astronomer. One should not fail to point out that of the nine known satellites of Jupiter, four were known to Galileo and four more were discovered at Lick Observatory. About 4,000 visual double stars and about 400 spectroscopic binaries have been discovered there. The dense companion to Procyon whose existence was suspected by Bessel some 75 years earlier was found with the 36-inch Lick telescope. Thirty-three comets, nineteen unexpected and fourteen returns of periodic comets, have been found by Lick astronomers.

Members of the staff have participated in many eclipse expeditions, for which funds have been generously provided by friends of the university, notably Charles F. and William H. Crocker. An expedition was sent to northern California to observe the total solar eclipse of January 1, 1889; another was sent the same year to Cayenne, French Guiana, to observe the eclipse of December 22. Both of these expeditions were successful, as was the next one, sent to Mina Bronces, Chile, for the eclipse of April 16, 1893. The Lick party which went to Japan to observe the eclipse of August 9, 1896, was unsuccessful because of heavy clouds.

It was the party sent to India to observe the eclipse of January 22, 1898, which introduced the moving-plate technique of Campbell. This expedition was successful, as was the one to Georgia for the eclipse of May 28, 1900. May 18,

1901, found another Lick group in Sumatra successfully recording another total solar eclipse, despite clouds which threatened failure.

Of the three parties sent out from Lick Observatory to observe the eclipse of August 30, 1905, the one in Spain had good skies, the one in Labrador was defeated by clouds, while the one in Egypt had poor seeing. In 1908, Lick astronomers saw the eclipse of January 3 from Flint Island, a coral atoll in the South Pacific.

The expedition to Kiev, Russia, for the eclipse of August 21, 1914, was probably the least favored of all; clouds spoiled the eclipse and the outbreak of the European war impounded the eclipse equipment. It was only with difficulty that the observers themselves were able to get back to the United States. For the eclipse of June 8, 1918, a Lick party went to the state of Washington, where their observations were successfully made.

The eclipse of September 21, 1922, stands out among the Lick expeditions, since it was the photographs taken by the Lick party in Australia which provided one of the few successful verifications of the deflection of light by the sun's gravitational field in the amount predicted by Einstein.

The Lick expedition to Lower California for the eclipse of September 10, 1923, was unsuccessful because of weather conditions. On April 28, 1930, and August 31, 1932, total solar eclipses were successfully observed in California and at Fryeburg, Maine, respectively. One may be reasonably certain that Lick parties will observe important eclipses of the future and that friends of the university will

THE MT. HAMILTON ROAD, NEAR THE OBSERVATORY.

continue their generous support of such expeditions.

It will be noted that no mention has been made here of the splendid work carried on at the Students Observatory of the University of California at Berkeley under the direction of Dr. A. O. Leuschner. Another article would be needed even to sketch the achievements of this branch of the astronomy department of the university.

To bring the story of the Lick Observatory up to date, something must be said of the new photographic telescope now under construction. In 1934, the Carnegie Corporation of New York made a gift of $65,000 to the observatory to pay for a 20-inch photographic refractor. It was planned that this telescope should cover a field in the sky six degrees in diameter and record stars as faint as the nineteenth magnitude in a two-hour exposure. The design of the lens was made by F. E. Ross; its construction has been placed in the hands of J. W. Fecker, of Pittsburgh.

The specific problems proposed for study with this new instrument are the rotation of the galaxy as evidenced in the motions of the very faint stars and the distribution of the faint extra-galactic nebulae. If the next fifty years finds the new telescope being put to as good use as the thirty-six inch Lick refractor and the thirty-six inch Crossley reflector have been in the last fifty years, no one will deny that the money has been well spent.

In conclusion, the author wishes to acknowledge his indebtedness to many sources of information, in particular, to his friends at the Harvard College Observatory. It is hardly to be expected that an article such as this, dealing with recorded history, will be highly original; the most that one can hope is that it be reasonably accurate and not too biased.

A METEORITE SURVEY

By Dr. H. H. NININGER
DENVER, COLORADO

FUNDAMENTALLY, rocks may be divided into two groups—*Accretionary* and *Terrestrial.* The former have arrived from space recently enough so that their structure and composition are predominantly those that characterized them extra-terrestrially. In the latter the characteristics are mainly those which have been acquired through an interaction of terrestrial forces.

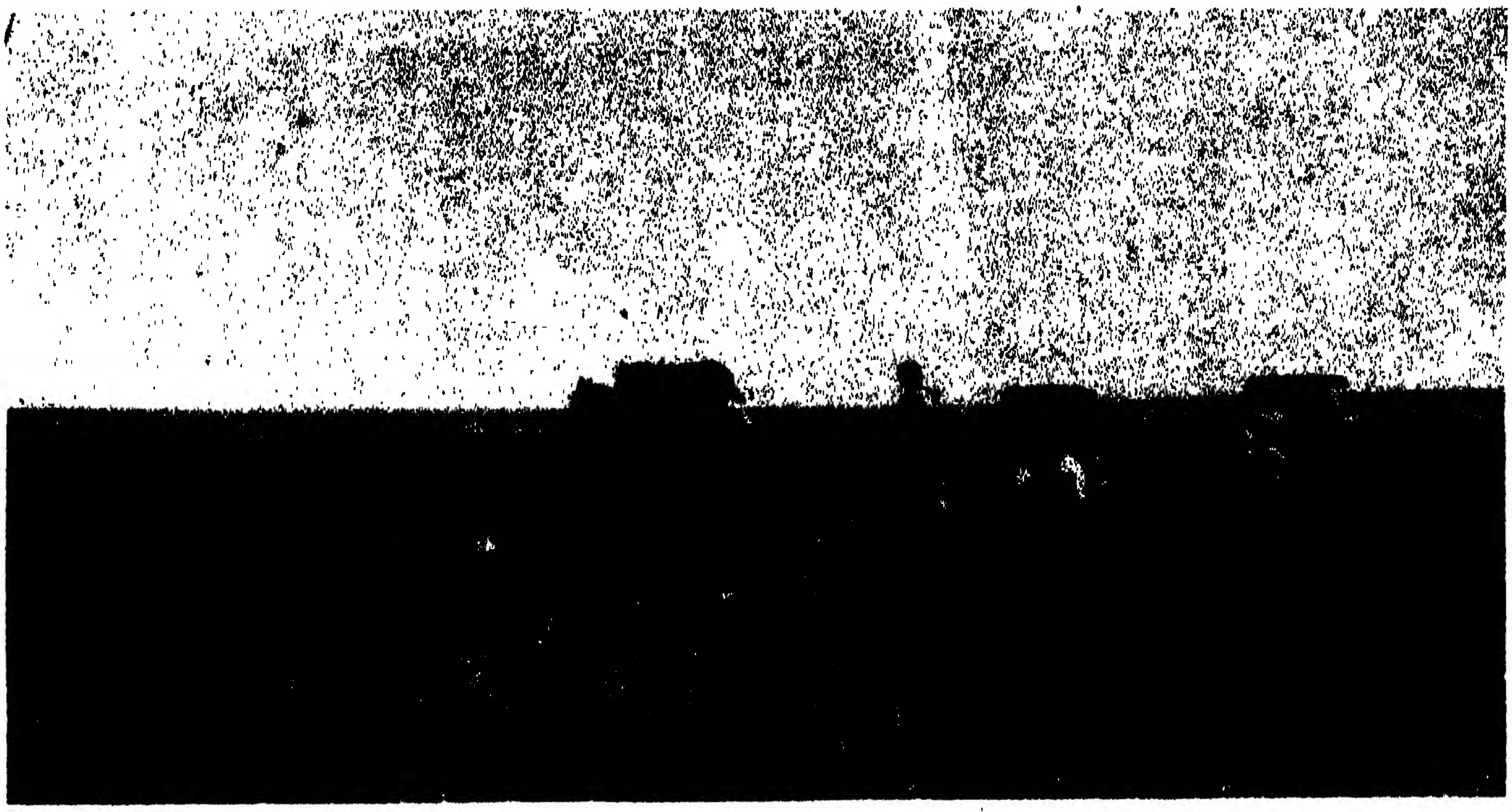
The discovery that matter falls to the earth from space is a comparatively recent one. The earliest scientist to advocate such an idea seems to have been Chladni, who published a treatise setting forth this belief in 1794. The hypothesis was soon after verified by witnesses to such arrivals, the shower of stones at L'Aigle, France, in 1803, constituting the most undeniable demonstration of the fact.

From the earliest discovery of meteorites they were regarded by scientists as being qualitatively of primary importance, and their structure and composition were investigated with utmost care. Only their scarcity and consequent high valuation were allowed to interfere with the most exhaustive analyses of their contents.

Quantitatively, meteorites received very little attention. There were those of course who realized the possible importance of the increment of cosmic material, and Lockyer went so far as to present in a very elaborate form the meteoritic hypothesis as the method of stellar and planetary evolution. His approach, however, was purely hypothetical and was not accompanied by any convincing body of factual evidence. Apparently the hypothesis has never been taken very seriously by the professions of astronomy and geology.

In 1873 Proctor had suggested that the lunar craters may have resulted from the impact of large meteorites or asteroids. G. K. Gilbert later (1893) elaborated on this idea and depicted in detail how the structure of the lunar craters conformed to what might be expected from such impacts. However, when he came to apply this hypothesis to the Arizona impact crater then known as "Coon Butte" he rejected his own hypothesis pronouncing this great landmark the result of a steam explosion, and staunchly defended this conclusion to the end of his life, even against the growing belief among his contemporaries to the contrary. We now know that his first idea was correct and that this great landmark has resulted from the impact of meteoritic matter.

In 1904 Chamberlin and Moulton advanced the planetesimal hypothesis as to the origin of the earth. But in all his geological writings Chamberlin seems to have carefully avoided identifying the present infall of meteorites with the growth of the planet. It is probable that he once hoped to demonstrate this identity. But with the facts then available regarding the rate of meteorite infall he concluded that only a layer one foot thick would accumulate in fifty billion years. This estimate was based upon the total weight and distribution of meteorites then known and the theoretical mass represented by the estimated fifteen or twenty millions of small meteors appearing in the earth's atmosphere daily. Probably, if Chamberlin had been able to accept larger estimates regarding the present infall of meteoritic matter it



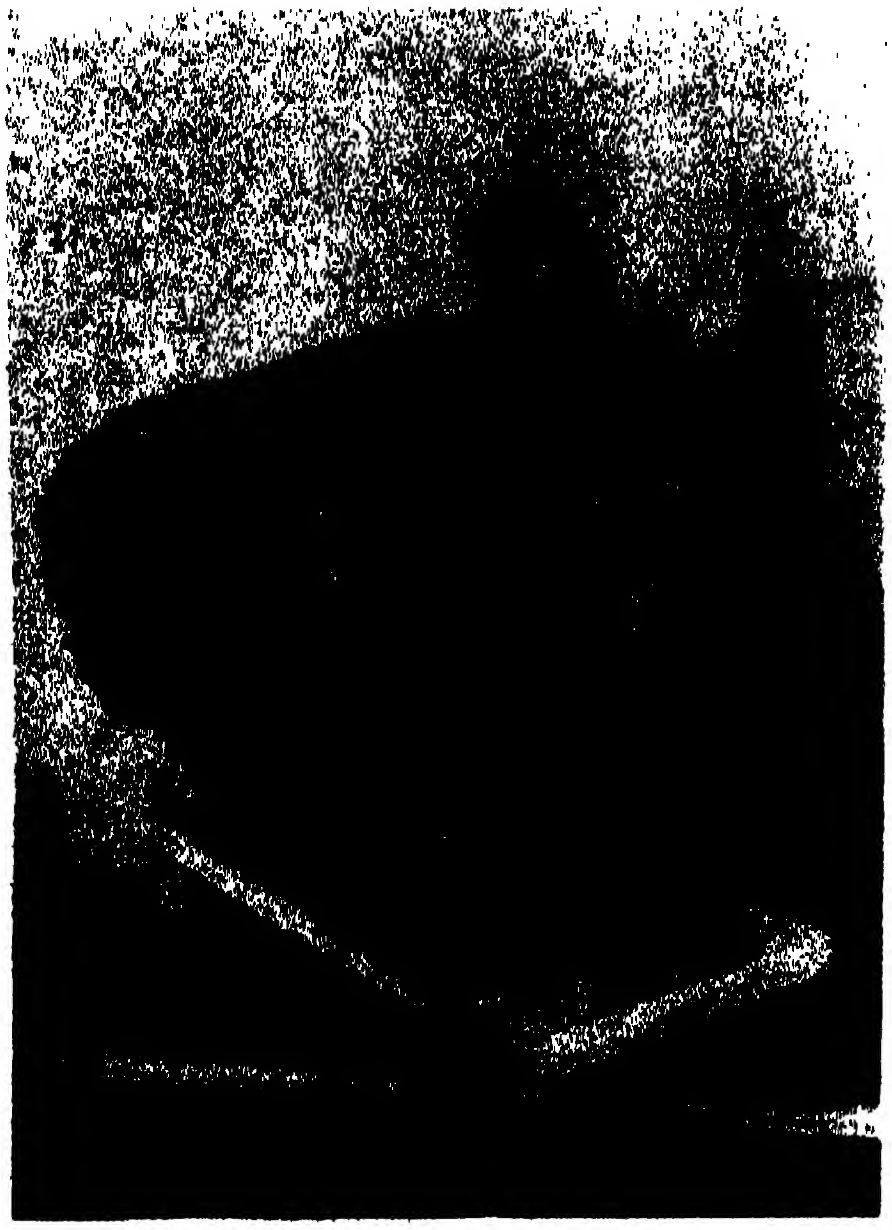
THE SITE OF THE NEWLY DISCOVERED "METEORITE-CRATE" IN KIOWA COUNTY, KANSAS. THIS "BUFFALO WALLOW" HAD BEEN FARMED OVER FOR MANY YEARS BEFORE PROFESSOR NININGER DUG FROM IT A HALF TON OF METEORITES.

would have been much to his liking. His refusal to accept higher estimates is evidence of his extreme caution as a speculating scientist.

The estimates used by Chamberlin regarding the mass represented by small meteors has been seriously questioned and the writer is one of those who believe that a study of infallen meteoritic material and of the phenomena accompanying such falls presents conclusive evidence of much larger masses involved.

When it comes to the consideration of the only other source of facts regarding the rate of meteoritic infall the writer has long cherished the belief that more complete data were obtainable. In 1923 a plan for the systematic search for meteorites was conceived by the writer and support for this idea was sought in an interview with the late Dr. Geo. P. Merrill who was eminent in the field of meteorite studies. Dr. Merrill considered the idea unsound and attempted to dissuade me from the attempt. Other sources of support were sought without success whereupon it was decided to proceed independently in the hope that the high prices then being paid for meteorites by museums and collectors might pay the cost of the venture—providing it should prove successful.

The plan was put into action on a small scale in that year as an avocation from a college professorship and has been carried on more or less intensively ever since. Success was very tardy in arriving and had it not been for two rather good finds at the first which had been largely responsible for generating the idea, the plan might have been abandoned, for during the succeeding six years no visible results came from the effort. During these six years there were times when our recurrent disappointments led to a critical re-examination of the facts on which had been based our conviction that a proper search would prove fruitful. Always we turned from such critical examinations to resume our efforts with the same confidence that, eventually, we must succeed. Finally in December, 1929, a twelve-ounce fragment of a stony meteorite arrived from the



GLADSTONE, N. MEX., STONY METEORITE WEIGHING 100 POUNDS DISCOVERED BY AN OBSERVANT FARMER WHO HAD BEEN PRIVILEGED TO EXAMINE THE NININGER LABORATORY FIELD EXHIBIT.

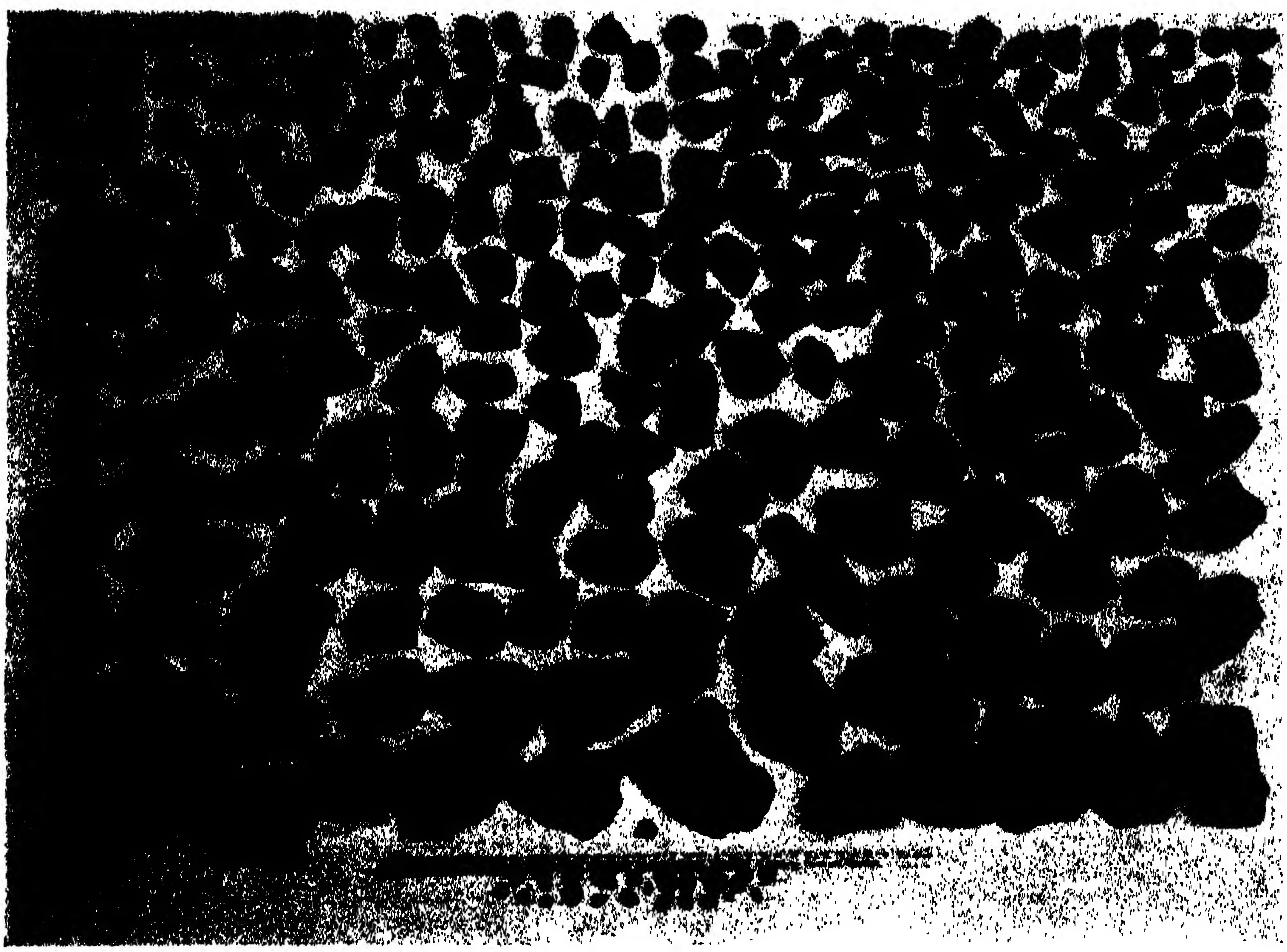
HUGOTON, KANSAS, METEORITE. THE YOUNG MAN IS J. D. LYNCH, JR., WHO, AFTER HEARING DR. NININGER LECTURE, CONCLUDED HE HAD PLOWED UP A METEORITE. AN INSPECTION CONVINCED DR. NININGER THAT HE HAD TORN OFF ONLY A CORNER OF ONE. THE 770 POUND STONE SHOWN IN THE EXCAVATION WAS FOUND BY DR. NININGER IN THE SEARCH WHICH ENSUED.

vicinity where we had worked more than four years before. The vicinity from which it had been brought was immediately visited and the ensuing search yielded more than a hundred pounds of material! Needless to say our plan was not abandoned.[1]

Our plan of search consists of a campaign among rural populations designed to acquaint the farm and ranch dwellers with the appearance and importance of meteorites. Directions are given for simple field tests to distinguish meteorites from terrestrial rocks and for specimens a price is offered as an inducement to all to keep on the lookout and report them.

The campaign is carried on mainly by means of lectures in high schools, before men's, boys' and women's clubs, through the distribution of leaflets on the Recognition of Meteorites, and by the use of local newspapers. All lectures are illustrated by specimens of the type most commonly found and warnings are given as to the kinds of terrestrial rocks, which, in the respective communities are likely to be confused with meteorites. This we call the general search. Wherever this effort results in the discovery of an unrecorded fall we subsequently conduct what is termed the intensive search. This consists of a house-to-house canvass and in some cases personal field work by a member of our staff. Even after the intensive canvass has been completed our visits to the community are frequently repeated in order to maintain the proper

[1] While this paper was in preparation a 20 pound stone arrived from this same area. All tests indicate that it is a part of the same shower as we located 10 years ago. This is an illustration of the manner in which our survey actually works.



PLAINVIEW, HALE COUNTY, TEXAS, METEORITES

THIS GROUP OF STONY METEORITES WERE COLLECTED AFTER A GREAT MUSEUM HAD SUPPOSEDLY COMPLETED THE COLLECTION OF THIS SHOWER. THEY HAD SECURED A TOTAL OF TWELVE STONES, AGGREGATING 68 POUNDS. THE NININGER LABORATORY COLLECTED 421 STONES AGGREGATING ABOUT 900 POUNDS.

interest in finding and marketing meteorites.

It is at once evident that if a search can be made successful and the yield of this celestial fruit is materially greater than had formerly been assumed, then this new information becomes of utmost importance in all considerations regarding the origin and history of our planet. By a careful study into the nature and rate of alteration undergone by meteorites in the soil a reasonable estimate may be arrived at regarding the period of infall represented by the harvest gathered. Such data would for the first time elevate our discussion of the question of earth-building above the plane of pure speculation and furnish a factual basis for a theory of planetary evolution.

Two things have strongly impressed the writer in the carrying out of this survey. 1st. *The enormous inconsistency between the amount of meteoritic matter actually collectable in a given area and the extremely small amount formerly recorded for the same area.* 2nd. *The extreme difficulty which we experience in the discovery of this material even in regions where the amount finally collected is surprisingly large.* For example, in an area where a large shower had occurred and where we collected about three hundred stones aggregating about eight hundred pounds from approximately ten square miles of level farm land, four years were required to accomplish the task after our initial discovery. What is even more impressive is the fact that this entire crop

of stones had eluded four different efforts on our part to find meteorites in that vicinity previous to the beginning of our success. Such facts suggest the probability that no search can ever be made to approach completeness. They also suggest that enormous quantities of meteorites may escape us entirely since our intensive program (so far) has been applied only where a fall has been discovered in a given region.

Early in our experience we perceived that the methods commonly employed in the collection of a discovered fall were quite inadequate and we adopted the practice of a follow-up search. Some of the results were as follows: 1st. Where two small stones, weighing together 850 grams, had supposedly constituted the entire fall we collected seventy additional stones weighing 16,000 grams. 2nd. Where twelve stones had been collected aggregating about 31 kgs. we collected 418 individuals weighing about 460 kgs. 3rd. In an area where a half dozen irons had been reported we collected forty-five additional. 4th. In the famous Brenham or Kiowa County field which yielded more than a ton of material between 1890 and 1910 we discovered a meteorite crater measuring 36′ by 55′ and from it collected about 1200 pounds of altered meteorites, besides collecting about 800 pounds of well-preserved meteorites outside the crater.

Please understand that our policy does not in any case permit our entrance into a field which has been discovered by another party until after the discoverer has "completed" his task of collecting and has abandoned the search.

Our most important work, however, is the discovery of unrecorded falls. It is here that we are constantly at work, systematically covering the Great Plains area as opportunity offers. In order to economize as much as possible we work in selected spots as guided by our discovered samples. For example, a sample arrives from Johnson county, Kansas. We forthwith go to Johnson county and if possible visit all of the schools in the county—an area of perhaps 900 sq. miles. This promotes the collection of the fall discovered, facilitates the mapping of its distribution, and also gives opportunity for new discoveries. In a number of instances we have discovered more than one fall to be present in the same county. In a few cases finds were duplicated in the same township (36 sq. miles). By reason of this "spotted" method of procedure it will be noticed that our finds are scattered over a very wide territory of some 400,000 sq. miles while as a matter of fact we have really covered by our general search something like 60,000 sq. miles of this area. Our intensive search has been applied to only a few hundred square miles.

Altogether the field program of the Nininger Laboratory (now incorporated as the American Meteorite Laboratory) has directly resulted in the discovery of eighty-four different meteorite falls. Only two were witnessed falls, both of which were surveyed and mapped by the writer preceding their discovery. Besides our direct results other workers have "taken as a cue" our plan of work and after receiving instructions in the methods employed have discovered about a dozen new meteorites during the last five years.

As may readily be imagined, the carrying out of such a program involves a great expense—some thirty to forty thousand miles of automobile travel per year, hotel and other expenses, a large volume of correspondence (chiefly concerned with reports on samples erroneously suspected of being meteorites), the printing and distribution of literature, payment for meteorites, photographs, chemical analyses, the execution of maps, etc., etc. In spite of our increasing success we still

find the discovery of meteorites a very expensive form of research, for an individual undertaking.

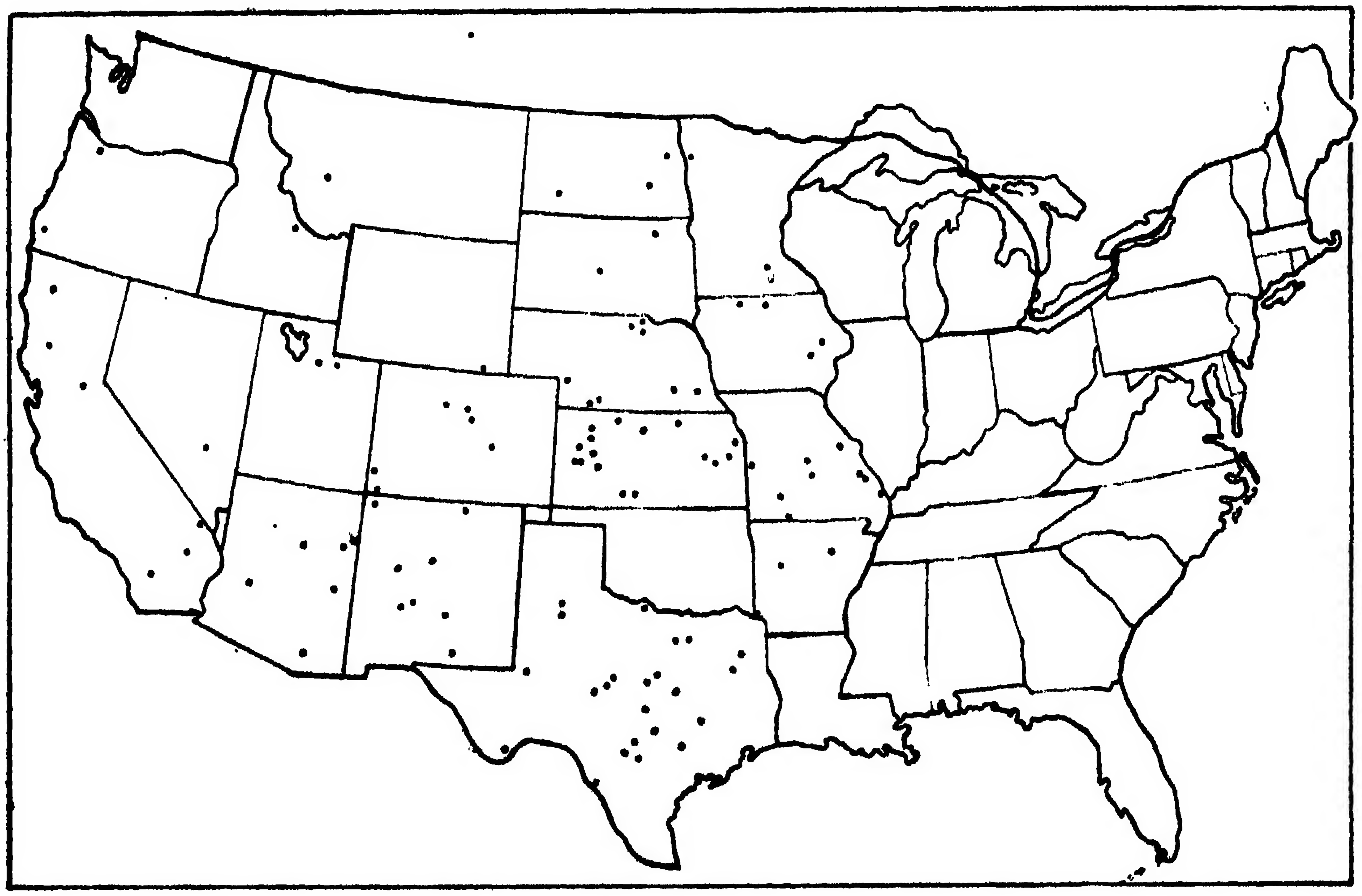
When compared with other lines of investigation in the fields of astronomy and geology, however, we see that the cost is small if viewed in the light of its great significance. Ours is the most fundamental of all geological problems. It definitely links together the works of the astronomer and the geologist, besides furnishing a very lively challenge to the petrographer and the mineralogist, the chemist and the physicist. Aeronautical engineers will learn much from the study of meteorites before they master the stratosphere.

Unfortunately a method of meteorite discovery was devised too late to be applied effectively in many areas of the earth's surface. We find our efforts most successful in those regions where the native sod was broken out by the generation yet living, and in regions where the soil is relatively free from terrestrial rocks and dense growths of vegetation. A reasonable density of population is desirable and the cultivation of the soil is an important factor. The lowering of the general soil level over large areas by the recent widely deplored dust storms has been responsible for several good finds and it is expected that other similar finds will be made as we have opportunity to push our search into additional territory.

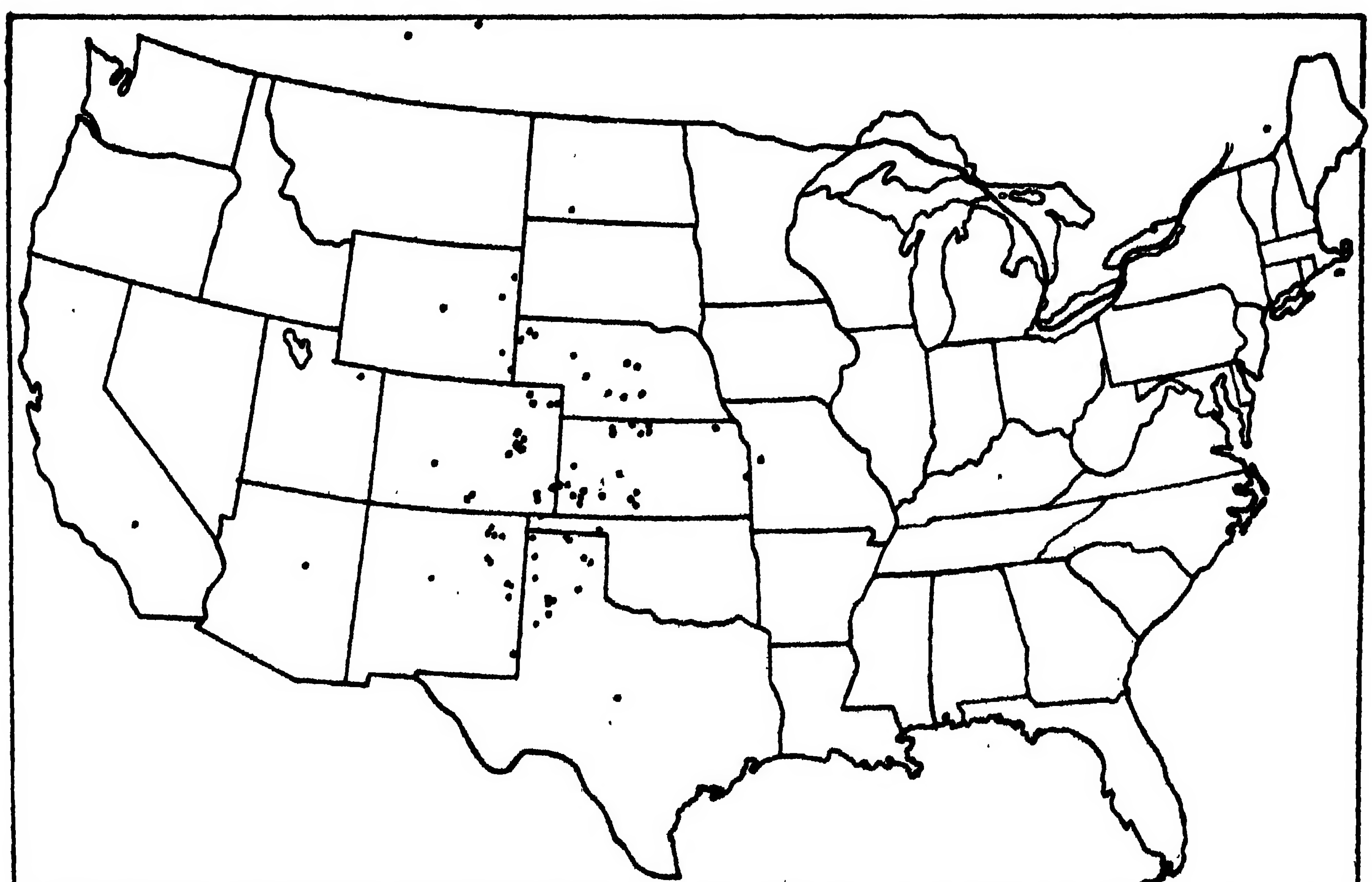
Publicity in metropolitan newspapers and in popular magazines unavoidably accompanies our activities. This can not be escaped, where the nature of the work has such a popular appeal, save at the expense of developing a reputation for discourtesy. We have not found this sort of publicity effective as an aid in our search. By it the volume of our correspondence is enormously increased; but out of some 2000 samples received through this type of publicity only two meteorites have been found. The work involved such a mass of correspondence (we answer all inquiries) and in the examination of such a number of samples renders it impractical. On the other hand where we appear personally before groups and permit the personal handling of specimens the ratio of true meteorites to spurious specimens submitted is reduced to perhaps 1 : 25 or 1 : 50.

Geologists have sometimes complained that our program together with the publicity which it occasions thrusts upon them a burden of examining a multitude of useless samples. To this we reply that they are paying the penalty for their neglect of the subject of meteorites in their courses. The public—even the college-trained public have never been given an opportunity to know this most interesting subject. Hundreds of professional geologists have told me they never had seen a meteorite and not a few have actually seriously questioned their existence!

From the standpoint of pure science there is no more excuse for a man being trained as a geologist without his knowing how to recognize a meteorite than that he should be unable to recognize an ammonite as being a fossil. We can not expect all geologists to be intimately acquainted with all of the different falls of meteorites nor with all of the various species of fossils; but he should be able to distinguish a meteorite from other rocks just as he is able to know that a foraminiferous limestone is not an igneous rock. Surely no geology student should be graduated from the general course without having been privileged to examine representatives of the principal groups of meteorites in the form in which they appear in the field, and have pointed out to him their most diagnostic characteristics. When the geology of meteorites has been properly presented in geological courses the burden of examin-



MAP 1. LOCATIONS OF ALL METEORITES RECORDED WEST OF THE MISSISSIPPI RIVER PREVIOUS TO 1923.



MAP 2. LOCATIONS OF METEORITES DISCOVERED BY DR. NININGER AND HIS ASSOCIATES FROM NOVEMBER 1923 TO NOVEMBER 1937. THIRTEEN OF THESE ARE IRONS. TWO ARE STONES WHOSE FALLS WERE WITNESSED. THE REMAINING SIXTY-SIX ARE STONES OF UNWITNESSED FALL.

MAP 3. LOCATIONS OF STONY METEORITE "FINDS" (STONY METEORITES DISCOVERED, THE DATE OF WHOSE FALL IS UNKNOWN) WEST OF THE MISSISSIPPI PREVIOUS TO 1923.

ing spurious specimens will be distributed and soon the general public will have contributed many valuable discoveries.

We expect to continue our field program to a point where we shall be able to speak intelligently regarding the amount of meteoritic material in the soil of the earth. By a determination as to the approximate period of time represented by this accummulation we shall then be able to speak intelligently regarding the rate of increment of matter from space.

In the accompanying maps No. 1 shows the location of all of the falls discovered previous to the initiation of our program, a period of about sixty to eighty years of residence in the territory concerned. No. 2 shows the location of the discoveries made by our survey—mainly during the past seven years.[2]

[2] Since November, 1930, the Colorado Museum of Natural History has coöperated in this survey. Other institutions, chiefly the U. S. National Museum and Harvard University (Department of Mineralogy), have assisted by the purchase of meteorite specimens which were offered for sale. The program has also been assisted on numerous occasions by Dean M. Gillespie and O. Stanley Dresher and in one instance by W. F. Bingham, all of Denver, Colorado.

GUGLIELMO MARCONI

By Professor DUGALD C. JACKSON
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

In 1844 the telegraph of Samuel F. B. Morse, which is the type impressed on our day, was put into successful operation.

In 1866 the efforts of Cyrus Field to produce a working transoceanic cable came to fruition.

In 1876 Alexander Graham Bell exhibited his newly invented telephone.

Thus the world was gradually drawn closer together in intellectual relations by means of new physical devices. To-day we are still closer because of international radio.

Some of my learned friends assert that our intellectual intimacy gained by language transmitted in signals or directly spoken across space has increased instead of ameliorating jealousies and irritations among nations. This view, in my opinion, is not founded on adequate observations of fact. We are now in a fraction-of-a-second physical world, as far as communicating with each other is concerned. This is an encourager for friendship between nations and between individuals. The frictions now existing in the world seem to be due fundamentally to human incapacity to come promptly to conclusions that favor compromise for mutual benefit, within ethical bounds. Conclusions reached, immediate intercommunication between individuals or nations results from now available physical facilities, and processes of negotiation can be carried on more directly than formerly.

Had Sir Edward Grey two weeks earlier in 1914 been able to reach the conclusion that Britain should and would, under its treaty stipulations, protect Belgium against any warring invasion, and had he then convinced the British cabinet on that point, the powerful influence of quick dissemination of the knowledge would have been, doubtless, an important preventive influence against the World War. The facilities for communication in a fraction-of-a-second physical world were available, but human adaptation lagged. Human adaptation however does become gradually more versatile and we come more and more to use quick communication with more friendly results. This gives hope for betterment among nations.

Responsibility for this fraction-of-a-second communication over the globe in the spoken word, stems romantically from the efforts of one man. Let us see how it came about!

On April 25, 1874, an Italian boy-baby was born in Bologna to the name of Marconi. He was the third son of his father. At his conception there must have occurred an extraordinary combination of chromosomes, for he was born a notable mutant of mental qualities and ambitions not obvious in his well-to-do and competent ancestors and brothers. His mind, beginning with early maturity, never ceased searching the infinitude of the unknown in nature; and his grasping of relationships enabled him to originate wireless electric communication and push it forward to extraordinary scope. He died in Rome on July 20, 1937, belonging in the temple of fame alongside of Alexander Graham Bell, Thomas Edison, Frank Sprague, George Westinghouse, Elihu Thomson and others, each of whom was parent of some great employment-giving and labor-saving industry in the field of electrical engineering. Bell and Thomson were foreign born, but turned American. Marconi never relinquished his fatherland, but he found in America an early assured and wide recognition.

Successful research men who are interested primarily in identifying additional phenomena of nature, or in discovering the relationships of such phenomena, are

very eager to peer into nature's guarded enclosures. Usually they are not ambitious for spectacular acclaim or for big money; but, being human, they are charmed by reasonable recognition. To such men, the problems and routine of patenting, and the restraints of secrecy in carrying on investigations, are distasteful. Utility for their results delights many such, but to feel under obligation to mould the results into that utility tends to appal and disconcert them. Such men should be supported by endowments. They belong in educational institutions, and endowed institutions for research, because they usually delight in the contact with young and fresh minds.

Add another taste or desire to the just spoken-of instinct for peering into nature's guarded preserves—the desire to make each discovery of immediate extensive utility to mankind—and the great discoverer-inventor is produced. When born to the world he must have in him the origins of discriminating mathematical (*i.e.*, analytical) powers which will aid him to conduct explorations, imagination for arousing a vision of a promised land, curiosity for inciting experimentation, penetrating powers for observing results of analysis or experiments, synthetic intelligence and enthusiasm which guide invention. Such a man was the Marconi who was born in 1874. We will now examine the phenomena of his productive life, beginning with its background.

Hans Christian Oersted, professor in the University of Copenhagen, announced to the world in 1820 his experimental proof that an electric current coursing in a conducting wire disturbed a magnetic compass-needle standing in the neighborhood of the wire. This information spread to the intellectual centers of the world as rapidly as the then state of transportation and communication of intelligence permitted. The year 1820 was on the eve of the development of steam railroads, the electric-telegraph was still unborn, and intelligence was transmitted by couriers or by horse-drawn coaches. The announcement from Oersted created lively interest wherever received. The results of its stimulation on the minds of Ampere and Arago in Paris are well known. I have seen it stated that, years later, Michael Faraday in London said of the Oersted discovery, "It burst open the flood gates of a domain in science, dark till then, and filled it with a flood of light."

Immediately upon the publication in London of Oersted's discovery, Humphrey Davy, professor in the Royal Institution, took a copy of the paper to the laboratory and he and Faraday (then an associate of Davy) went over the experimental work. Faraday's mind was inflamed, and in 1821 he produced continuous motion from the reactions between an electric current and a magnet. Subsequently, he made the cardinal discovery of the relations called electromagnetic induction, and he espoused the concept of fields of force and lines of force. His epochal work was accomplished while he was Fullerian professor in the Royal Institution.

Later on, this very work of Faraday stimulated James Clerk Maxwell to reflection and ultimately, when professor of experimental physics in the University of Cambridge (England), he published an epoch-making treatise on electricity and magnetism which contained extended mathematical discussions of electromagnetic waves. Maxwell became a professor in a Scotch college when twenty-five years of age. He entered his professorship in the University of Cambridge at forty. His theory of electromagnetic waves aroused ardent discussion and considerable controversy, especially as it involved the phenomena of light, but no one immediately undertook to determine its validity by the pragmatic test of experiment. Indeed Maxwell died (at 48 years of age) before the validity of his theory was demonstrated by the experimental work of another college professor.

Heinrich Hertz, professor in the Carls-

ruhe Polytechnicum in Germany (later at Bonn University), was the man who made that demonstration. It was accomplished in the latter part of the decade of the eighties and its publication deeply stirred the scientific world. By that period, railroads, steamships, electric-telegraphs, all contributed to rapid dissemination of important information, and both scientists and amateurs in Europe and America began a mad scramble of experimentation with the interesting phenomena that Hertz's work had opened to observation. Among these investigators were distinguished professors of physics like Righi of Bologna, Branly of Paris, Slaby of Berlin, Lodge and Crookes of England. Talk arose of electromagnetic waves becoming the instruments for the transmission of intelligence through space, but none had achieved as yet the genius and courage as an inventor which were required to bring such a conception to embodiment.

The field had been leveled, ploughed and cultivated and lay awaiting the advent of a planter (an inspired inventor) who could plant the seed and harvest the crop for the benefit of mankind, by adapting these electromagnetic waves to the wireless transmission of human intelligence over long and short distances. This inspired genius was the already referred to Marconi boy (Guglielmo), born in Bologna, Italy, in 1874, the youngest of three sons of a father of some wealth. His mother, a second wife, was musically minded and Irish, of the Jameson family, of whiskey distilling fame. Bologna in 1874 was nearly ready to celebrate the centenary of the theory regarding electric reactions propounded by Luigi Galvani, the first of the great contributors to electrical knowledge hailing from that city and the two-hundredth anniversary of whose birth has now been recently celebrated by the city and university.

The boy Marconi seems to have been delicate and without interest in hard physical play, but he loved reading and was a devotee of fishing, horseback riding and sea travel. His schooling was principally by tutors and his own reading and experiments. A biographer tells of his interest in the letters of Benjamin Franklin regarding experiments with electricity, and how he reproduced Franklin's plan of causing a bell to ring at times of thunderstorms by the effect of electricity drawn through a lightning rod. He was still at the moderate age of twenty when his attention became attracted by the phenomena which directed the passion of his life.

Heinrich Hertz (the already referred to German college professor) died on January 1, 1894, seventy-five years after Oersted in Copenhagen was, philosopher-like, turning over in his mind the problem of relations between electricity and magnetism. As is usual in obituaries of men of note, those published upon Hertz's death summed up the influence of his work and, in some instances, described his experimental investigations at considerable length. A journal containing such an obituary fell into the hands of young Marconi while he vacationed in the mountains in 1894. This was the stroke required to detonate the passion of genius. Marconi later described his impressions thus: "It seemed to me that if the radiation could be increased, developed and controlled, it would be possible to signal across space for considerable distances. My chief trouble was that the idea was so elementary, so simple in logic, that it seemed difficult to believe no one else had thought of putting it into practice. . . . From the first, the idea was so real to me that I did not realize that to others the theory might appear quite fantastic." Others had, indeed, thought of the application, but none had had the call of invention required to find the way to the embodiment.

It is the part of genius to bridge by invention an apparently impassable gulf. But when the bridge is established and the gulf has been crossed, an achievement

that previously, as an hypothesis, appeared to be beyond the limit of human powers, now (in its embodiment) seems very simple. That is a characteristic of many great inventions. At any rate, Marconi's genius was now on fire and he reflected, sketched and planned during the rest of the vacation so that he could enter upon actual tests immediately upon returning to his father's estate. He was a few months past his twentieth birthday.

His first trials of his idea were failures, like Faraday's first trials of his ideas regarding the relations of electromagnetic induction; but soon he was able to transmit signals short distances. He proved to his father that this result was actually the outcome of his project and became the happy recipient of 5,000 lire, given to encourage his activity. (In those days the lira was worth about twenty American cents.) He was using an induction-coil with spark gap for an oscillator-transmitter and a resonating gap for receiver, following Hertz and Righi; but the results were disappointing. Something more was needed! Signals could be transmitted, but only over short distances.

This was still a laboratory matter in the spring of 1895. Others had already achieved perhaps as much, but that was in the course of ordinary lecture-room experimenting and Marconi had his ambition set on the space-transmission of intelligence from man to man.

Marconi's solution was startling. It arose from inspired thought. He electrically connected one terminal of his oscillator-transmitter to the ground and the other terminal to a bit of conductor at the top of a pole. He introduced into his receiving circuit a device called a Branly coherer, and here also one terminal was connected to ground and the other ran to the top of a pole. In these pole-supported conductors were the first embodiments of the elaborate antenna structures with which we are now all familiar, at least as an object on the landscape even if not as a part of our technical acquaintance.

With this arrangement he gained distance of transmission in spite of the crudeness of his apparatus. The sending and receiving antennas, associated with grounded circuits, had achieved his end. Wireless telegraphy was a fact. Innumerable refinements have since been introduced but, in all instances, Marconi's fundamental embodiment remains. Tuning of circuits, choice of frequency, new transmitters and receivers, directional antennas, substitution of speech for telegraph signals, broadcasting, all are refinements, improvements, or extensions, but all hang as embellishments on the original gem. All who have practiced invention know well that at that time the mental exaltation of Marconi must have been high. Marconi is one of those who learned early that the long road of invention is rough but that it provides some glorious vistas.

The announcement of his results, made in 1896, created great excitement among the physicists of the world, who began an ardent discussion of the mechanism of the waves, their emission and capture by the sending and receiving antennas, their velocity of propagation (was it indeed the same as the velocity of light?), how penetrative were they, could they follow around the curvature of the earth, and many other factors. There also arose a flood of mathematical and experimental investigations in this field of phenomena, the doors to which were so unexpectedly thrown open.

It is said that the Italian government took no interest in this project of its youthful citizen, when Marconi called it to attention in 1896. Therefore he went to England, where he took out a patent covering his fundamental embodiment—the first patent ever taken out for wireless telegraphy specifically described as based on electric waves. He was welcomed in England and given hearty cooperation in extending his demonstra-

tion. Then, in July, 1897, a company was incorporated to support his investigations and to enter the field of commercial wireless telegraphy. At that date a transmission distance of about ten miles had been achieved. This company secured Marconi's rights to wireless telegraph inventions throughout the world, except in Italy. The latter Marconi held out for the benefit of his fatherland.

There followed, in England, many years of great activity. Stations were set up for communicating with lighthouses and with ships at sea. Exacting research was also carried on. During this period Marconi invented the application of tuned circuits to wireless transmission and reception, thereby improving the effectiveness and selectiveness of wireless telegraphy, and also enabling, if desired, a multiple of messages to be simultaneously transmitted or received on an antenna. This has a bearing on wireless telegraphy and telephony of importance almost equal to the primary invention patented in 1897. In these early days he also visualized radio processes of transmitting direction-bearings to ships; and he was constantly on watch for hitherto unobserved and unexpected phenomena and was occupied in inventing improvements. He by now had gathered around him a group of notably competent aids who also were active in devising improvements. Distance of transmission was steadily increased. "Marconi wireless" became the talk of two continents.

About this time an American reporter said of Marconi: "He is a mere boy, with a boy's happy temperament and enthusiasm, and a man's nervous view of his life work. His manner is a little nervous and his eyes a bit dreamy. He acts with the modesty of a man who merely shrugs his shoulders when accused of discovering a new continent."

There was drama in all this development. Flinging readable signals into space, to be picked up perhaps a hundred, perhaps two hundred, miles away was itself dramatic as a realized entity, although not difficult to conceive as a dream-effect. But now this drama began in good earnest. Ships in trouble began to call for help by their installed wireless apparatus; and others, in response, to rush to give aid. Then came that exhibition of confidence and courage at its height which is allowed in the life experiences of but few men, and occurs but once (because of its transcendent character) in the life of any man. For Marconi this was the dispatch of readable signals from the southwestern portion of England to St. Johns, Newfoundland, two thousand miles away—the letter S, three dots in Morse telegraph code, repeated according to a predetermined manner. Some were skeptical when this achievement was reported; but the scientific world was thrilled, although it then (December, 1901) did not know how the electric waves could follow the curvature of the earth and some had denied the possibility.

Marconi's achievements already had raised him to a level of high respect for his ability and his sterling reliability. The New York *Times* commented on the feat of transatlantic signalling in a manner that is worthy of repeating:

> It can not have escaped notice of those for whom the subject of wireless telegraphy has even a news interest, that to establish the fact that the feat had succeeded of transmitting intelligible signals in prearranged order and frequency of occurrence no other evidence was needed than Signor Marconi's unsupported and unverified statement. Immediately on receipt of telegraphic intelligence from Newfoundland that this feat had been accomplished representative engineers of the world were interviewed, and without exception their response was: "If Marconi says it is true, I believe it!" . . . No higher tribute could have been paid by the world of science to an inventor than was paid Marconi by this unquestioning acceptance of the announcement that he had succeeded in accomplishing the seemingly impossible.

A few months later Marconi, on the steamship Philadelphia, while crossing the Atlantic Ocean from Europe to

America, received signals and messages over a still greater distance; and the time had come to establish plant for commercial service between these two continents. It was on this trip that Marconi also made the important observation of a difference between night and day in the strength of signal transmission. Now the world did indeed take notice, and honors flowed in to Marconi. In mid-1902 the Czar of Russia met Marconi when he entered a Russian harbor during some of his observations, and on leaving him said, "I am assured your invention has tremendous possibilities. It should prove a blessing to all."

The drama now turned to averting or ameliorating tragedy. Various rescues of small groups of people from shipwreck had been made on call by wireless. Then impressively great achievements brought the life-saving possibilities of radio spectacularly into the public consciousness. In 1909, 461 people on board the sinking steamship *Republic* were taken off in safety by the steamship *Baltic*, called to the rescue by radio, while other ships similarly brought to the scene stood by. This was near the harbor of New York City and various large ships were within easy distance.

In 1912 the disaster to the steamship *Titanic* occurred, and the far-away *Carpathia*, called by radio, rescued 712 lives. Some or all of the 1,517 who were lost would have been saved, it was thought, if all vessels in the neighborhood at that time had been suitably equipped with the wireless apparatus. In 1913 the people who stayed with the ship, to a total of 521, were saved from the flaming *Volturno* by ships called to the rescue by radio. In this instance the difficulties of rescue in stormy seas were lessened by means of oil on the water from an oil-carrying ship called to the spot by radio.

By this time, travellers and shipping people became convinced that all steamships ought to be provided with wireless telegraph equipment and that great passenger ships should carry two or even three operators, so that safety supervision could be always available. The first wireless shipping report had been published by Lloyds in 1910, the importance of wireless to the mercantile marine having then already become recognized, but this was ship-to-shore business and the rescue problems were now proved to be largely ship-to-ship communication problems.

At 5 A.M. on November 11, 1918, went forth from the Eiffel-Tower radio-station in Paris one of the most pregnant and dramatic announcements ever carried by electric waves. It came from the authorship of Marshall Foch and announced the end of military hostilities in the world war. It read: "Marshall Foch to the allied commanders: Hostilities will cease at 11 A.M." This word of the cessation of hostilities is said to have reached by wireless one half of the allied troops who then numbered several million men. Marconi is reputed to have said in later years, "I prefer to think of the lives that have been saved by wireless, rather than the uses to which it might be put in wartime."

We now, in our present year, have before us the convenience of radio (*i.e.*, wireless) communication in a flash of time, by telegraph and by telephone, into all parts of the world where there is a need for it. Radio has expanded into various other branches which are aside from the original objective that stimulated Marconi's mind. The radio has become a commonplace of life through the results of steady expansion and improvement. Such a tremendous industry founded on one man's inventions, and affected by the researches and inventions of rivals following him into the field, arouses many disputes regarding the fundamental priority of the inventions and the patents describing them. Marconi's work was no exception, and his great fundamental patents were warmly contested. As the development of radio unfolded, the early awe-inspiring wonder

among the people disappeared, and the whole enterprise became a simple public affair. Marconi said some half-dozen years ago: "I think I may say that the people will cease to wonder at wireless. The only wonder will be that there was ever a time when it was unknown."

When we contemplate the magnitude of influence inherent in radio as we know it, which is truly the blossoming from Marconi's pioneer work, we can feel gratified that Marconi's fundamental patents have been generally sustained. The attitude of American courts is indicated in the following paragraph from a decision of 1905.

> It would seem, therefore, to be a sufficient answer to the attempts to belittle Marconi's great invention that, with the whole scientific world awakened by the disclosures of Hertz in 1887 to the new and undeveloped possibilities of electric waves, nine years elapsed without a single practical or commercially successful result, and that Marconi was the first to describe and the first to achieve the transmission of definite and intelligible signals by means of the Hertzian waves.

In the foregoing I have said little of the man and his personal life outside of his great work of invention and development. This is appropriate, for that great work absorbed him and was his life in a large sense. Nevertheless he was twice married. Once, the end was unhappiness and divorce. The other marriage seems to have turned out adorably. Three children from the first marriage, I know little of. The child of the second marriage, a daughter now nearly eight years old, is reputed to be a very charming little girl.

Upon his death, Marconi possessed decorations of high order from many nations; academic honors from many universities; and many famous medals and prizes, headed by the Nobel Prize for Physics conferred on him in 1909. He was Senator of the Italian Kingdom and hereditary Marquis by creation of His Majesty the King of Italy. In January, 1928, he was appointed President of the Italian National Council of Research; in November, 1930, he became President of the Italian Royal Academy and Member of the Council of the Fascist Party; and in February, 1931, he was appointed by His Holiness the Pope a member of the Pontifical Academy of Sciences. The friendship of the King and Queen of Italy and of the Duce during many years, with which was associated the helpful cooperation of all government authorities, eradicated any unhappiness that Marconi may have had originally on account of the coldness of his government toward his project in its youth, and his funeral was an official affair of great dignity accompanied by a spontaneous outburst of respect and mourning by the Italian people.

Marconi's productive qualities as an inventor arose from a nature illustrated by a comment from him which is reported by one of his biographers:[1] "I'll tell you, if you set your heart and soul in a thing, you can do it." The aid which he derived from originating in a well-to-do family is illustrated by his comment when asked what he would have done had he been poor. He said, jocularly perhaps, "I don't believe I would have been an inventor. I might have been a sailor." He loved the sea, but the inventive spirit burned strong within him and it is not safe to assert that he would not have been an inventor in some degree, even if he had been a poor sailor following the sea.

It takes a genius to write a *good* short story in the literature of any language. Many short stories start well and others have good endings. Those are written by individual authors of ordinary merit; but one who is a genius can write a short story that is satisfying in both start and finish. It often is different with fundamental inventions in the scientific world. One genius is not enough for such. It usually is necessary to expend (in sequence) the efforts of one or more investigators on discovering the needed funda-

[1] Orrin E. Dunlap in "Marconi, the Man and His Wireless," published by The Macmillan Company.

mental facts in nature's gallery, and of an additional individual (the inventor) to complete the chain and mould the applications of those facts to the use of man. In the example of wireless communications (or radio, as we now call it), the principal sequence comprised four matchless men—Michael Faraday, James Clerk Maxwell, Heinrich Hertz, Guglielmo Marconi. Although we usually give first place to Faraday, it is truly difficult to say which was the greatest of these men, for each contributed largely to the comfort and convenience of men and to knowledge from which farther convenience can be distilled as inventors seize the opportunities. It is more reasonable to ascribe first place jointly to Faraday and Maxwell because their investigations and discoveries were so fundamental that various great applications have stemmed out of their work and others may yet do so. Nevertheless, Marconi's work uncovered so many previously unnoted phenomena that we are not yet able to put a limit to the ultimate outcome. Faraday said of himself "In early life I was a very lively, imaginative person, who could believe in the 'Arabian Nights' as easily as the 'Encyclopedia,' but facts were important to me and saved me. I could trust a fact." And again, "Without experiment I am nothing" and "But still try, for who knows what is possible." Also, "Let us encourage ourselves by a little more imagination prior to experiment." These phrases could be equally applied to Marconi's qualities, but Faraday's mind was directed to identifying fundamental phenomena and their relationships, while Marconi's was set on producing useful applications.

There is a moral in the sequence above named, which holds interest for those who wish to advance human comfort and convenience, and I can not refrain from expressing this moral to you. Faraday, besides many other great achievements, thought out and experimentally demonstrated the phenomena of electromagnetic induction and also outlined the conceptions of fields of force and lines of force; Maxwell thereafter synthesized such ideas by means of powerful mathematical treatment, thereby premonstrating the existence of electromagnetic waves in space. Hertz experimentally proved the truth of Maxwell's predictions regarding electric waves, and provided means for producing and for detecting electromagnetic waves of a range of wavelengths. The way was then open for the inventor, Marconi, to carry forward, and wireless communication of intelligence sprang into being as the child of his labors.

Such is the character of sequences through which nowadays arise the great inventions from which influential industries spring. The age of the individual inventor struggling in scientific darkness to bring forth a great invention, as Watt did for the steam engine, Fulton did for the steamboat and Goodyear for the vulcanization of rubber, is in its waning period, if it is not already gone altogether. The day of sequential scientific discovery, followed by invention which completes the chain and produces results out of which important industries spring, is with us. Even Watt, Fulton and Goodyear worked from platforms of vague knowledge established by sequences of their predecessors.

We are now applying to man's purposes the more refined and abstruse features of nature's phenomena. This presses a strong emphasis on the importance of scientific research of fundamental character if we wish to have continued the progress of invention that contributes new industries for our advantage. Support for such research of fundamental character into nature's phenomena, provided in the way of endowments and government appropriations, is an important basic factor in raising to higher levels man's comfort and convenience, and in improving the mutuality of interests between men. I commend this idea to your reflective minds as a primary principle which is emphasized out of the work of such inventor-geniuses as Marconi.

SCIENTISTS SOMETIMES TELL THE TRUTH

By the late Dr. MAURICE C. HALL[1]

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ONE of Mark Twain's maxims is to the effect that truth is the most precious thing we have, and, therefore, we should economize it. The statement is a blend of fact and of the cynicism characteristic of Mark Twain and other judicious persons who, on critical inspection, find the world, and more especially the behavior of people, something less than satisfactory. It is an appreciation of the fact that, in a society that speaks very highly of truth, personal indulgence in truth telling is a mischancy and hazardous occupation for thoughtful individuals. In this respect, the present time is probably no worse than former times, and may be somewhat better. In all ages it has been customary to stone the prophets, to ostracize any Aristides the Just that might arise, to compel the recantation of Galileos or burn them at the stake, to imprison innovators, to deride Fultons and Langleys, and to lop off the heads of such heretics and freethinkers as do not concur in the dicta of the current magnificos of State, church and similar collective organizations. The precise forms change, but the basic reactions are identical, and, for this or that reason, we are economical of truth.

Yet the present time differs a bit from former times in that we now have a very large group of persons devoting themselves to ascertaining the truth by somewhat precise and critical procedures in lieu of seeking it by revelation, introspection or the ratiocination of logic without benefit of observation or experimentation. These persons call themselves scientists. As students of science these scientists receive a certain amount of attention, but as subjects of scientific research the group has had too little attention. A few persons, such as Ramón y Cajal, have given them passing consideration, as I do here, but what a scientist would regard as a critical study of the group has never been made. It is pointed out here as a good subject for research.

Quite visibly, scientists actually seek for truth in their occupation as scientists. Equally visibly, scientists do not seek for truth to any notable extent outside of their occupation as scientists, when acting in their capacity as human beings. As human beings they are constrained by the same internal and external inhibitions that operate on all human beings. Internally they are shaped by the same forces that establish all childhood patterns of behavior. They have the same incapacity for examining their patterns by the critical methods of science, for justifying their behavior by the demand for adequate evidence, and for sustaining their childish beliefs by the demand for sound reasoning. Anthropologists and ethnologists have traced the roots of most of our childhood behavior and beliefs to primitive sources, but scientists in general are content to regard those findings as applying to other human beings, and to ignore the possibility and probability that they themselves are behaving in the customary affairs of life, outside of their laboratories, precisely on a par with Eskimos, Fiji Islanders, Toltecs and cavemen. Economists and sociologists have clarified some aspects of problems of production, distribution, crime and maladjustment, but scientists in general discuss these subjects with the same light touch that has characterized their ancestors back through untold generations. It is obvious that they inherit their religion, politics, morals and manners, and follow them as

[1] Died May 1, 1938.

deviously and uncritically as did the men and women of ancient Tyre, Gomorrah or Carthage.

The reason for all this faulty behavior is sufficiently obvious. We have nothing better than human beings from which to make scientists, and such material is clearly defective. As human beings, we have our thinking complicated by our emotions, and limited by our childhood beliefs. These things are forces that push us from the straight path of reason, or even stand astride the path and hold us back. The result is, in some ways, pathetic. Our work as scientists lacks the sparkle of originality and individual thinking because we are set and molded in youthful habits of thought. We follow patterns taught us, and slip into grooves from which we extricate ourselves with difficulty, if at all. To a great extent, our research follows some blueprint as evidently as does that of a carpenter or mechanic, and often shows as little, or even less, evidence of art or craftsmanship.

When we scientists have arrived at some morsel of truth, we display, somewhat too often, a bit of disregard for truth and precise honesty in the presentation of our findings. Too often, a joint paper presents the work done by the junior author, without the saving grace of a statement to that effect. Rationalizations which are not quite sound and scientific are alleged as arguments justifying papers that should fly the Jolly Roger of piracy. Directors of research, from project leaders up to the Herr Doktor Direcktor, are in special danger of playing the rôle of Captain Kidd, and some few degenerate into intellectual parasites incapable of taking two borrowed or stolen ideas and deriving from them a third idea of their own.

In the course of 30 years, I have observed various experiences bearing on this matter of truth and honesty in scientific publication. On one occasion, a writer lifted about four pages from another man's papers, and incorporated it in his paper without benefit of quotation marks, credit or bibliographic citation. While the original author appreciated the compliment, and certainly was not harmed by the procedure, the borrower's action was hardly in line with the nicest considerations of honesty and courtesy. While in the field on one occasion, a scientist pointed out to a younger scientist two species of animals of which he stated that one would probably be the intermediate host of a certain parasite with a then unknown life history. One of the younger man's associates undertook the problem in life history, and found that one of these species was the intermediate host. The report of the work gratefully acknowledged assistance from many persons, and the omission of the older scientist's name was probably because government scientists are supposed to be paid for such work, and have no amateur status entitling them to compete for such trophies as acknowledgments. One writer has blithely chucked a brick at another in print, in connection with a subject with which the latter had no direct connection whatever, and only a very remote and devious historical relationship, the brick, apparently, being heaved purely in a spirit of good, clean fun. As age comes on, it becomes increasingly interesting to note that ideas set forth by one scientist many years ago are commonly charged to writers of 3 or 4 years ago, who, naturally, are not citing authority for accepted ideas, a form of carelessness unworthy of scientists. The 1936 report of a highly important and useful organization contains a statement in regard to recent research on anthelmintics, and concludes by saying: "From these anthelmintic studies it appears that there is now available for uncomplicated hookworm disease a safe and effective drug in tetrachlorethylene." It is gratifying to report that these 1936 findings were confirmed over a decade earlier by the two scientists who proposed the drug

in 1925 as an effective remedy for hookworm infestation, and have been confirmed by a decade's extensive experience in human and veterinary medicine as a safe remedy. Concerning these things, one need have no emotional reactions. It is not necessary to write letters to the authors or the editors, since the printed records stand available to all critical scientists who seek for facts in the literature and history of science, as well as in their laboratories, but they are mentioned here as the evidence from writers, who are here kept anonymous, as to the fine disregard for truth and fact that characterizes too many scientists on too many occasions. This disregard, as it appears in the performance of persons engaged in the pursuit of truth, is something of a disappointment.

On the other hand, and most curiously, a sentence from one of my papers was referred to by a writer, within five years after its publication, as "an American saying." When I read this, I feared for a moment that I was on the way to become a legendary figure or a solar myth.

If our performance in science is not quite in keeping with our high status as seekers after truth, it is hardly to be expected that we will make a much better showing in our performance as individuals. The motto of legendary Poictesme, *Mundus vult decipi,* is not fantastic—the world does wish to be deceived. This world that desires and admires deception, sleight-of-hand, magic and miracles is no safe place for truth or persons who are unrestrained in the telling of truth. It is a world in which those who wish the crown of martyrdom may find it, but the scientist has his work to do, and commonly manifests no eagerness to shorten the little span of life in which he may gratify his curiosity about this and that tiny segment of an extremely interesting and thought-provocative universe.

If the findings of scientists who range among the stars, or through the buried strata of the earth, or into the chromosomes, do not in all respects confirm the thoughts of the prophets, law givers and persons in high places, it is convenient, and possibly advisable, to confine our findings and our derived opinions to selected colleagues, or hint at them, as I do here, in such glittering generalities as convey nothing specific that might give offense to someone's cherished childhood beliefs.

Such behavior on the part of the scientist is in keeping with the basic and not too admirable habits of the human animal. For externally, as well as internally, the scientist is inhibited and restrained. Life is still a struggle for existence; and physical, economic and social suicide are alike distasteful to normal human beings. Life is short, and the scientist's art not merely long, but endless. While thousands tramp the streets in search for work and sleep in "flophouses," the scientist will feel no eagerness to join them as evidence of his distaste for a society in which reward bears no visible relationship to merit. If society displays a hypocritical attitude in paying lip service to virtues which it does not practice, the scientist will invite no display of intolerance by specific public criticism, even though he fail to pay compliments. He will continue to follow in his laboratory the methodology of controlled experimentation, careful observation and sound reasoning, so far as he is capable of such difficult business, and, if he is optimistic, he will trust that the human race will some day apply the same methodology to the matter of government, religion, society, business and similar collective enterprises.

For the individual must adjust to society, and that adjustment can be a quite happy one only in a non-existent society of intelligent and social-minded individuals. To-day's emphasis in teaching is increasingly on the development of individual thinking, and psychology is emphatic as to the evils of mob psychol-

ogy and mass thinking. Yet this teaching is precisely the road to maladjustment to society in a world in which no man and no woman may live in anything closely approximating honesty other than by an outward and apparently whole-hearted acceptance of the mores of the mob's 14-year-old intellects.

Until society applies the methods of science to our community life, the living of all thoughtful persons will be warped and deviated. Surely, thoughtful persons can not and do not conform their living to modes readily detectable as vestigial remnants of the mores, taboos and tribal customs of neolithic man. Thoughtful persons can not subscribe to ideas contemporary, and on an intellectual par, with those of troglodytes who lived in a flat world infested with the prehistoric equivalent of gnomes, elves, werewolves and other demons who were kept at bay only by the use of appropriate charms, rituals and ceremonies, or the occasional sacrifice of such individuals as the medicine man might select. It is enough that the long-departed dead lay their hands on us through heredity, mixing in us desirable and undesirable things, and by the element of chance confirming a biological doctrine of predestination. It is too much that these dead of long ago should still determine all our living, and that we should not settle today's problems for ourselves as they settled them for themselves. But in the doing of this, thoughtful persons shape their living to such outward conformity, such private evasions, and such inward adjustments as may meet the demands of the moronic herd and still allow some measure of personal and individual life. Such a life is a blending of outwardly honest and inwardly false living with outwardly false and inwardly honest living. It is an unsatisfactory and unhappy compromise between an individual that seeks for truth and a society that prefers falsehood. It is, in fine, the same mode of life as that of all crooks, villains, hypocrites, and social offenders of high and low degree, and so may be put down in the customary set terms as a failure of adjustment to society.

As usual, our set terms are a bit too inflexible, a bit misleading. As a pattern followed alike by good and bad, intelligent and mentally defective, one may conclude from such a mode of life that, although a primitive savage may happily obey his tribal taboos, civilized society is so constituted that honest adjustment to its pattern is possible to no human being whatsoever. This is probably true, and may, to some extent, account for the enthusiasm with which mankind welcomes the dictator who promises miracles, and proposes to pull from his hat or sleeve, after the fashion with which prestidigitators produce white rabbits, a social organization molded more closely to the heart's desire of all. The scientist, who has lost his childhood belief in fairy godmothers, will feel little stir of surprise when the Promised Land of the dictator turns out to be a land in which all are molded to the pattern of the dictator, and no other person may call his soul his own. Yet the scientist will continue to hope for a society in which one may live honestly and speak the truth somewhat oftener than sometimes.

In the individual life of the scientist, he likes to think that reason sits at the wheel and steers his car. It is, unhappily, only a conditioned thinking that makes him believe this. For the car is full of back-seat drivers. The emotions, good and bad, insist on this road; the endocrine glands on that; magic compels this stop; pretense compels that start; and, in the end, compromise settles most of the arguments between the driver and the back seat. And compromise is the foe of truth and honesty. So we live falsely and compromisingly, and in defiance of the categorical imperatives of science. Nevertheless, some of us live thus only reluctantly, and it is depressing to note that philosophers, metaphysicians

and even some scientists in high places, under visible pressure, openly set such a value on reason and such on the back-seat drivers as lead to the conclusion that it is a high philosophy to let one of the back-seat drivers take the wheel. Emotions which to our minds are not laudable are given preference—hates and phobias and childish pride in this or that unreal thing. In sum, the "amor fati" of Nietsche, an acceptance of life, nay, a rejoicing in life, as capable of no improvement except as a blind fate directs it, is set above reason. In the interplay of choice and chance, chance is elected ruler. It is a rejection of the brain as a reasoning instrument and as a determinant in the destiny of mankind, and is a selection of automatism, as determined by adrenal glands and such lower organs, as better than conscious intellectual effort. Yet the scientist may question whether reason can be thrown out of the car, and whether there will be any gain or any less conflict from putting reason in as a back-seat driver. For this restless mind is as indestructible and as active as the emotions, and it, too, if it can not steer, will grab the wheel from the driver on occasion, and resume it as soon as possible.

It is the fashion of some militarists, dictators and philosophers to laud the dangerous life, lived in the expectancy and realization of war, as a sharpener of wits and a developer of courage. The scientists may look with some contempt on this philosophy. If we wish to fight, we need no wars, international or civil, to provide fights. Nature still fights us with her weapons of heat, cold, famine, disease and death, and in the war against Nature in the defense of mankind there is ample score for the qualities of sharp wits and courage. The conquest of disease affords ample opportunity for daring, suffering and death on the part of the scientist. It calls for a quality of calm, intellectual, individual courage that is far superior to the emotional mass courage of men disciplined to unquestioning obedience to orders. The war on disease has developed mental alertness far more evidently than has warfare of man against man, and intelligent persons in general evidently prefer science to military life. In the long lists of warriors in man's thousands of years of war, the really able generals can be counted on the fingers of both hands; a mastery of military strategy has been one of the rarest of accomplishments; and the tale of the world's battlefields is mostly a monotonous history of two opposing generals making mistakes until one makes a fatal mistake and the other wins by virtue of his opponent's greater stupidity. With all the flaws of scientists who can not measure up to a strict bill of specifications, the short history of science can present a long list of able men as competent in science as was Napoleon in war; scientists in general use strategy and tactics of a much more complicated sort than those of the military men, against enemies that moved by land, water, air and subterranean channels long before man had mastered anything but land movement; they master their strategy and tactics so well that they quite generally win the innumerable campaigns in which science engages; and the battle flags of science rarely bear the name of a battle-field from which science has gone away other than as a conqueror. The battles we have not won are mostly the battles we are still fighting.

Psychologists and sociologists tell us that man goes to war because his peacetime life bores him, it lacks the romance and adventure that he craves, it imposes responsibilities without compensatory rewards, and even to the minds of uncritical persons it is definitely not the thing which childhood pictured, which art and fiction paint, and which the heart and instincts desire. The blood of ancestral cavemen, soldiers and adventurers rebels at an overcomplicated and formal living in regimented modes. So thoughtful persons who love peace advise us to find an

attractive substitute for war if we wish to abolish war. The scientist has such a substitute. He has intellectual interests beyond those of generals, and he has the hazards of injury, disease and death from his work with radium, x-rays, explosives, poisons, bacteria, viruses and parasites. The scientist, engineer and explorer, the worker with hot steel and high-speed machinery, and all the company of those that fly the air, bore under rivers, fell great trees, and blast away cliffs—these need no war to make life adventurous.

But it is not solely the fact that the scientist's life has in it elements of romance, adventure and danger that makes it a substitute for the soldier's life. It has in it, intrinsically, those elements of truth and honesty which we need to make possible a satisfactory adjustment to life. Our peace-time life has in it so many elements of frustration and defeat that mankind turns readily from its subtle dishonesties to the simpler idea that one may match strength with an enemy on the battle-field much easier than he may match wits with a world of dishonesty that denies him, on lofty and legal and preposterous grounds, the right to earn a living, to play a dignified rôle as a worker who returns a *quid pro quo* to life for his living, and to enjoy this brief span of years allotted to him before he descends to dust and ashes. War itself may assume the more honest aspects of warrior combat, with an honest assumption, at times, that this is an admitted appeal to opposing strengths and skill, and it is often a bitter disappointment to the soldier that a war in which he thought he played an honest role as soldier and citizen turns out to have been fought for the low motives of so-called statesmen, and that when the diplomats sit down to arrange the terms of peace all of the soldier's ideals are forgotten, and the talk is of theft and oppression to be arranged. Surely, an honest life, in which one may tell the truth oftener than sometimes, would be a life in which peace might be maintained and war prevented.

To-day the ghosts of ancient war gods have come back from Antan to dethrone truth and reason and science, and to restore the old reign of magic and emotion and might. More than any other group, the scientist must resent and combat the return of these gods from the shadowy limbo to which science, more than any other force, has dispatched them. Even while the savage war gods are killing and mutilating civilian populations as they have not been killed and mutilated since the Middle Ages, it is still one of the most pathetic of to-day's spectacles to see outstanding scientists paying outward homage to the discredited and preposterous ideologies imposed on countries by the ghosts of Alexander and Ares. Mars may, for a time, defeat Minerva *vi et armis*, but the doctrine that might makes right may be inspected in the light of the fact that man has conquered the world by his brain, not his brawn, and that brains have not been conspicuously an outstanding feature of military men.

If all of this sounds a bit pessimistic, or if it suggests, unavoidably, the attitude of the elders in whom the fire is dying down, it is, nevertheless, an avoidance of the hypocrisy of smugness. Certainly, all is not well on a planet which reeks with gunpowder, and in which blood runs on battle-fields and before firing squads; in which famine and starvation march beside luxury and waste; in which frank expression of thought invites retaliation and suppression. It is a compliment to scientists that a scientist may say to them wherein we all fall short of the ideals to which we are, in some way and to some extent, committed. The preacher who speaks as frankly may face excommunication for heresy; the lawyer may invite being barred from practice for undermining the dignity, so-called, of the law and the courts; the law maker may be

charged with sedition and treason; and in matters in general any of us might be branded as bolsheviks, the current term for anyone who disagrees with us on any matter whatsoever.

Yet, even though scientists are courteous enough to listen to a statement of their shortcomings, what is the point in stating them? If there is a point, it is that science moves forward as the performance of scientists improves, and that by seeing wherein we fail we have taken a step toward a better performance. It is especially desirable that the younger ones among us should see wherein we have failed, and that the new generation of scientists avoid, to some extent, our mistakes. The new generation may realize, as we have not adequately realized, how essential it is that the scientist be honest with himself and his associates, even though we may admit, with suitable blushes for our cynicism, that he should confine his expressions of honesty, in most affairs, to such a few and carefully selected persons as can appreciate honesty. The young worker may realize that courtesy is one of the assets of personality, well worth practising in scientific circles, and even admissible, without penalty, in most of the affairs of life. He may learn that one may, at least, have the courage to face the truth, even though he restrain his expression of it, and may thus avoid the sin of self-deception. A younger generation of scientists may even make a slight impression on the world's way of thinking, and perhaps nudge it a bit in the direction of better thinking.

After all, the ascertaining and expressing of truth is our business to an extent that ranges beyond the aims of most groups. Justice Holmes has said that the business of a judge is not to see that justice is done, but that the law is enforced. Doubtless he was right, but it is a depressing thought when one considers by what uninformed individuals laws are made. Certainly the business of business is to make profits, but it seems an inadequate objective in a cheerless sequence of depressions, failures and unemployment, the results of a planless economic system managed by persons who need only capital or credit to engage in business, and subjected to no other demand for qualifications. The business of medicine is to make people well or keep them well, but it has long been a matter of worry to conscientious and thoughtful physicians that they should cure the sick in order to return them to slums, poverty, vice and crime, knowing that, when they go too far astray, a society on which lies the primary guilt of neglect and stupidity will settle with the delinquent individuals by the too simple expedient of executing them. By comparison with these other occupations, the scientist's search for truth seems exceptionally desirable. Not infrequently the scientist contributes in highly practical ways to the betterment of life and living, but, unfortunately, he can contribute little and very slowly to the human race in the way of improvement in its thinking, nor can he ensure that what he contributes in other ways will benefit those most in need of the benefit.

If we could assure ourselves of one thing, we could view the future of humanity with some degree of optimism. If we could but be sure that in his progress from *Pithecanthropus erectus*, or such other primates as you prefer, if we could be sure that with all his ups and downs, with all the peaks and troughs in his curve of development, man has made some little progress in his development of intelligence, as he has in his learning, and has come even a little closer to a desire for and an appreciation of truth, we might go from this earthly scene with some expectation that in time the world would be a place in which truth might walk in safety. For the scientist realizes that in all things there is a time factor, and that we have a reasonable expectation that man will have the benefit of a quite

ample time factor. We can specify a thousand years, or ten thousand years, as probably available for the working of such other factors as may lead to real progress, could we but be reasonably sure that the curve of man's history shows any upward trend of definite progress.

Without too definite assurance on that score, the evidence, nevertheless, suggests that man may have made progress along the lines of greater intelligence. It is a complicated and not a clear-cut progress. By comparison with the other animals, the human primate has forgotten how to be a good animal, partly, perhaps, because he has, to some extent and in one way or another, sought to suppress what he called the animal in him, forgetting that, as a rule, animals have some admirable qualities. They do not wage war on their own species, they do not complicate their living by the making of laws and rules that fit no individual whatever, and in general they manage to live in herds, flocks and packs with little need for extensive blood purges. Even the highly social ants and bees seem to have no such inadequate and badly suited rules and regulations as call for the large-scale punishments, banishments and disciplinary action which man, this miscalled social animal, has elaborated. It has remained for man to make of property something other than a thing of use and enjoyment, and to evoke from it hatred, envy, jealousy, greed, theft, violence, racketeering, war and the other unlovely and niggardly vices and misconduct that characterize this animal that regards himself as a human soul of a quality superior to the human animal in which it is domiciled. Nevertheless, one might judge that from the ameba to *Pithecanthropus*, there was some growth in intelligence, and, somewhat hesitantly, might affirm that among modern mankind there were I. Q.'s higher, by our standards, than that of *Pithecanthropus*.

As regards the search for truth, the evidence of progress is gratifyingly better. In the entire city of Syracuse, the Roman soldiery could find but one Archimedes to slay. To-day a well placed bomb might slaughter dozens of scientists, and if there are still few of these of a stature comparable to that of Archimedes, nevertheless a judicious selection of the time and place might easily result in the destruction of a National Academy of Science, and bring to some appreciative aviation officer a well merited sense of satisfaction. So we may say, quite candidly, that in these matters we have made progress.

To the younger scientist we might say that, apparently, the law of compensation is still in force. We still pay in one way or another for what we get, and the art of living, seemingly, consists in seeing to it that what we get is worth what it costs. The too casual thought of a world dominated by the herd thinking of low I. Q.'s and the mental aberrations of high I. Q.'s have developed ideals which are definitely unsound. Although it has been impressed on the plastic minds of our childhood that wealth, fame and power are the desirable things in life, we have the testimony of history and of those who attained these things that they quite generally lead to grief and disappointment. Fortunately, the scientist is not likely to be disturbed by the problems of wealth. If he attain any measure of fame, he will note, unless he take himself too seriously, that there is no great nourishment in achieving what any first-class gangster achieves to some extent, and that the friendship and regard of competent colleagues are better things. The power he may wield is the power wielded, not by personalities with the gifts of oratory, military skill and ruthlessness, but the power of fact, truth and reality at work.

If his teaching has been sound, he will realize that we know very little of the truth about anything, that what we accept as truth at the moment is accepted with reservations to the effect that our successors will find it faulty in one

respect or another, and that one reason we tell the truth at times, but not always, is that truth is difficult to grasp by any finite mind dealing with infinite things. In time he may achieve a gratifying modesty.

This modesty will increase as he realizes that human beings are ill-prepared to meet the specifications of a scientist. The possession of initiative, imagination, curiosity, technical ability, keen powers of observation, soundness of reasoning, precision of thought, intellectual honesty, and moral courage is something not granted in any large measure to the sons and daughters of men. Some two or three of these things we may have, but certainly not all of them.

With whatever modest equipment of this sort he may have, and with a realization of his limitations, the young scientist may still feel that in his practice of the art of living he is driving no bad bargain in investing his time and energy and intellect in a search for small fragments of truth and reality. Life is apportioned, in more or less equal parts, to work, rest or recreation and sleep. The scientist is usually one of the fortunate few that have congenial occupations, congenial and interesting associates and comfortable beds. He is paid to satisfy his curiosity, a happy arrangement for those who have any curiosity. When he has found some truth he can publish it, provided it is of such a nature or so worded that it does not conflict with established mores or business interests. In this land of freedom of speech and of the press, he can tell the truth—sometimes. In that respect it appears that the American scientist is fortunate above many of his foreign colleagues who must, in this modern scientific age, confine themselves to the authoritarian pattern which science long ago rejected.

At this time there is uncomfortable evidence that the right to tell the truth is in great and growing danger at home and abroad. Since the World War, governments have become increasingly hostile to the telling of truth and to all thoughtful people, including scientists. Diplomats—the superlative of the old series of liars, damn liars and diplomats—and super-diplomats in the form of dictators dominate the world's thinking and expression of thought. In this country we are developing a mode of expression from which one notes, with surprise and discomfort, that among our magnificos, criticism of the ability and uncertainty of the honesty of, at least, some business men and business methods is regarded as a form of treason.

If truth and truth telling is in danger, it concerns the scientist. Is there any likelihood that the scientist will do anything about it? Very little. With some confidence, we can assert that the scientist will follow the classical pattern of Archimedes, and will draw his plans in the sand or work in his laboratory, as he is doing in Spain and China, until high explosive terminates him and his work. As individuals or as a group, scientists can be expected to do little about a world bent on making itself unhappy.

In time, however, the scientific method may be expected to prevail. When that time comes, when government, politics, religion and business put off childish thinking and adopt the methodology of honest search for fact, truth and reality, scientists may tell the truth, and not merely sometimes. When that time comes, probably anyone can tell the truth. And that will be most agreeable to us. For, after all, the ascertaining and telling of truth is the business of the scientist, and an honest world in which one might live honestly should not present problems for the scientist in adjusting to society.

OUR MUSCLES AND OUR MINDS

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WHENEVER a person says he used his "brain" or asserts that his "head" is tired, he implies a theory of the mental life which finds little support in current research. Ever since it first received official notice in the writings of Gall and Spurzheim this alleged mental organ has been overworked in the explanation of behavior. By popular acclaim it is the brain which thinks, controls our actions, tells us how we feel and what we should do about it. In such deifications it is easy to discern the vitalistic countenance of the "soul" hidden behind a set of neurological false whiskers. The discovery of the sensory areas of the brain was taken as inescapable proof of the point of juncture between the material and spiritual universe and it was thought that all the difficulties of consciously directed action could be met either by introspective analysis or by the surgeon's knife. This idea is now so generally ingrained that mental healing cults have made rapid strides forward in decades when scientific progress leads in opposed directions. For while popular interest in the mind-body problem has languished in a fixational complex for the brain, important developments have taken place in the laboratory.

It was not until the search for centers specifically associated with the higher mental processes suffered a telling experimental disproof that the brain's claim to mental determinism was seriously questioned. In fact, very little interest was displayed in what made it function in the first place. By implication, the mind was regarded as a *tabula rasa* upon which external stimuli might write as they pleased, and the matter of inter-neural dynamics was quite neglected in the zeal to concoct a palatable scientific stew out of introspective observations on the flow of mental life and the brain processes hypothetically associated with them. Repeated demonstration of the linkage of brain processes with the total neuromuscular reaction sequence finally brought us out of this state of intellectual coma. The idea that the brain can carry on its traffic more or less independent of the rest of the body is now generally recognized as inconsistent and myopic. Instead of being merely handmaidens and servants to the brain, the muscles are seen as important regulators and determiners of its function. Physiological psychology has moved on to the more promising task of finding out the ways and means by which the muscles affect mental activity.

It is now generally recognized that study of the dynamic relation between muscular action and mental process leads especially to those maintained states of slight contraction known as muscular tensions rather than to the overt "phasic" activities such as occasion the moving of a limb. The relationship has been approached experimentally from two directions: the first varies some phase of behavior and observes the resulting changes in muscular tension; the second alters the tension of the subject directly and observes its effect upon performance. Both procedures have been used extensively and with remarkably consistent results.

Individuals who persist in completing mental work that has been disrupted or who engage in a second line of behavior upon frustration of a first, are found to

have increased muscular tensions. Compensatory reinforcements by way of increased tension also occurs in combating the deleterious effects of protracted work, as when an individual shows no decrease in objective work output but has to increase progressively his muscular "energy" input. Performance following severe sleep loss is often continued without objective decrement due to the muscular accompaniments of increased effort. Heightened tensions and excitability resulting from irritating experimental situations correlate with self-ratings of emotionality.

But while annoying situations, new tasks and serious thwart to activity in progress raise the tension level—habituation, learning and removal of inhibition are accompanied by relaxation. Both in the acquisition of verbal associations and in the development of sensori-motor habits, it seems that the curve of work output and the curve of supporting neuromuscular action are inversely related. In the initial stages of learning gross tension is apparently necessary to accomplish a minimum of output. As learning progresses, increased performance is accompanied by reduced tension.

It should not be inferred that tension can be increased indefinitely without adversely affecting both the quantity and quality of performance. Many activities, such as playing golf, are rendered less effective under excessive tension. Such evidence suggests that "consciously" directed action is sometimes facilitated and sometimes inhibited by muscular tension. Analysis of this basic problem has come largely from experiments where tension is altered experimentally and its effects observed on some standard test performance. Under "progressive relaxation" there is a reduction in sensory acuity and reflex response as well as in more complicated mental activities. Experimental alteration of the postural state indicates that different types of activity are inflected from facilitative to inhibitory effects at different points on a scale of gradually increasing tensions. Excessive tension raises output in simple motor performances and increases sensory acuity, but is harmful to tasks involving delicate eye-hand coordination and reasoning. Influencing factors other than the amount of tension are its locus in relation to the bodily parts engaged in performance and its timing. With these matters under control it is possible to describe for a given individual in a given situation his efficient working level, where a maximum performance output is attained with a minimum muscular input.

These results suggest that the older notion of the brain controlling the rest of the body should be replaced by its converse. Mental activity becomes a purely relative matter—and that relativity is supported largely through the muscular processes. The highest degree of consciousness or level of adjustive response carries over a limited range of reactivity. Mental processes suffer as the supporting postural substrate falls below or exceeds these limits.

We must be clear of two misconceptions, else we miss the main point of this interesting relation. One confuses muscular power with the ability of the integrative mechanism to use advantageously excitation derived from the muscles. The other attempts to postulate a one-to-one relation between specific muscular processes and specific mental acts.

Until recently, most people would have treated as absurd any notion that their mental processes were as intimately related to their muscles as to their brains. When suddenly assured that this is the case, they have difficulty in orienting themselves to the changed notion. Unable to understand just why his muscles

should be of any more importance to thinking than his heart or his liver, the average man desires to be on the safe side so far as mental vigor goes. And since psychologists have been none too articulate in explaining the relation of mind and muscle, he listens, perforce, to the more voluble claims of the physical culturists. Forgetting that the old adage, "a strong back and a weak mind," may still hold, he often jumps to the fallacious conclusion that a beautiful physique in and of itself will develop mental power. As a result many muscular nostrums have developed. Chiropractic offices are filled with patients awaiting "adjustments" calculated to restore their vitality. Department stores show all manner of ridiculous contraptions for rejuvenation of various parts of the body. The correspondence courses in muscle building do a thriving business, and the "daily dozen" has become an excruciating feature of many an already harried life. The pathetic thing about all this well-meant but generally misguided effort is that it has accomplished little that it apparently hoped to do. Insomnia is as prevalent as ever and the number of insanities which can be traced indirectly to neuromuscular hypertension is on the increase. Individuals who should have been drugged to sleep have often been urged to exhaust themselves further, while others who needed some exercise have tried to take a "rest and quiet" cure. To the stupidity with which man has always abused his neuromuscular mechanism there is now added a latent and misdirected solicitude for it. Mere drill in the outward signs of muscular exercise and relaxation will have little effect upon the mental processes. For if these are sustained by a backlash of excitation from the muscles, as we have reason to believe, adequate adjustment becomes a matter of effective use of the excitation in neural integration and not one of potential power. Doctors can thus advise rest, exercise or change of scene without limit, but unless their patients learn how to control their own energies, the value of the prescription is questionable.

But if the layman has been mistaken in his notion of the relationship of mind to muscle, many psychologists now seem to have been equally in error. When the search for the bodily processes associated with thought finally led to the muscles, it was a great day for the behaviorists. Most motor theories of consciousness developed by this school turned to the postulates of the completed circuit of the reflex arc. Consciousness was said to occur only when sensory stimulation of the brain eventuated in some specific motor response. All that was required to produce this mental froth was for some muscle group to act "overtly" or "tentatively" or "implicitly" and so complete a specific circuit through the complicated neural switchboard.

This idea has been very attractive to many because it offered a simplified method for the objective study of mental activity. All they would need in order to find out what John Smith was thinking about was to record the movements made by his tongue and larynx. It is in no way clear, of course, just why any one should assume that the tongue must be in motion when a man thinks. Few of us would call the social gabbler a deep thinker; for we have often observed that a person who handles words most fluently has actually very little to say. Much true thinking seems quite inarticulate.

But thought was a great stumbling block to the theorists and it had to be connected with some *specific* motor system. It was fairly logical to assume that one had the consciousness of red because a peculiar retinal impulse passing into the brain was shunted out along a given pathway to the eye-muscles; or that we

experienced sounds because of the motor adjustments made by the auditory apparatus. In casting about for an unassigned group of muscles with which to link thought, one of the early behaviorists hit upon the larynx. The vocal apparatus of many individuals has subsequently suffered all manner of indignity in an attempt to verify this hypothesis. Movement analyzers have been tied to the tongue and the voice box prodded with sensitive needle electrodes. The results are all disappointingly negative. There is wide-spread muscular activity during thought (including swallowing and tongue movement), but there is practically no evidence that such activity is specifically localized in the throat.

Now we have seen reason to believe that some sort of muscular activity is an essential condition for mental activity. But the notion that each particular brain process is supported by activity in particular muscle groups is open to serious question. For one thing, it is neurologically naïve. There was a time when it was plausible to assume that the ringing of a special cortical "bell" was accomplished by the closing of a sensory-motor circuit through it. But it is now generally apparent that neural processes are much more complicated than this "reflex" theory of mind concedes them to be. The balance of evidence favors the view that the nervous system acts as a total integrated unit rather than as a mere aggregation of isolated pathways. The principles of irradiation, induction and altered excitability are more or less foreign to the analogies of the telephone system.

Another and more reasonable explanation of why muscular action is essential to mental action is reached by going directly to the nerve-cell. The brain is made up of a mass of these cells, each of which will respond in varying degrees to the same externally initiated energy change, depending upon its state of physiological readiness or "vigilance." The vigilance of a nerve cell is determined by the substances carried to it by the blood and by the excitations irradiating from other nerve centers. A cell may fail to react adequately when there is a lack of either nutritive material or intra-neural stimulation. Asphyxiation, narcosis and the presence of other toxic substances in the blood lower the efficiency of cell-reaction by lowering its vital condition. Lack of neural excitation irradiating from other centers seems to have much the same effect. It now becomes a question of where this intra-organic stimulation is derived. The proprioceptive excitation delivered into the central nervous system by the processes of muscular tension seems to supply a major portion of it. When the muscles relax, a great deal of the nervous current necessary to normal brain functioning ceases; external stimuli are relatively ineffective in eliciting responses in the absence of such reinforcement. Sleep results not so much from toxin substances in nerve cells as from the restriction of muscular activity.

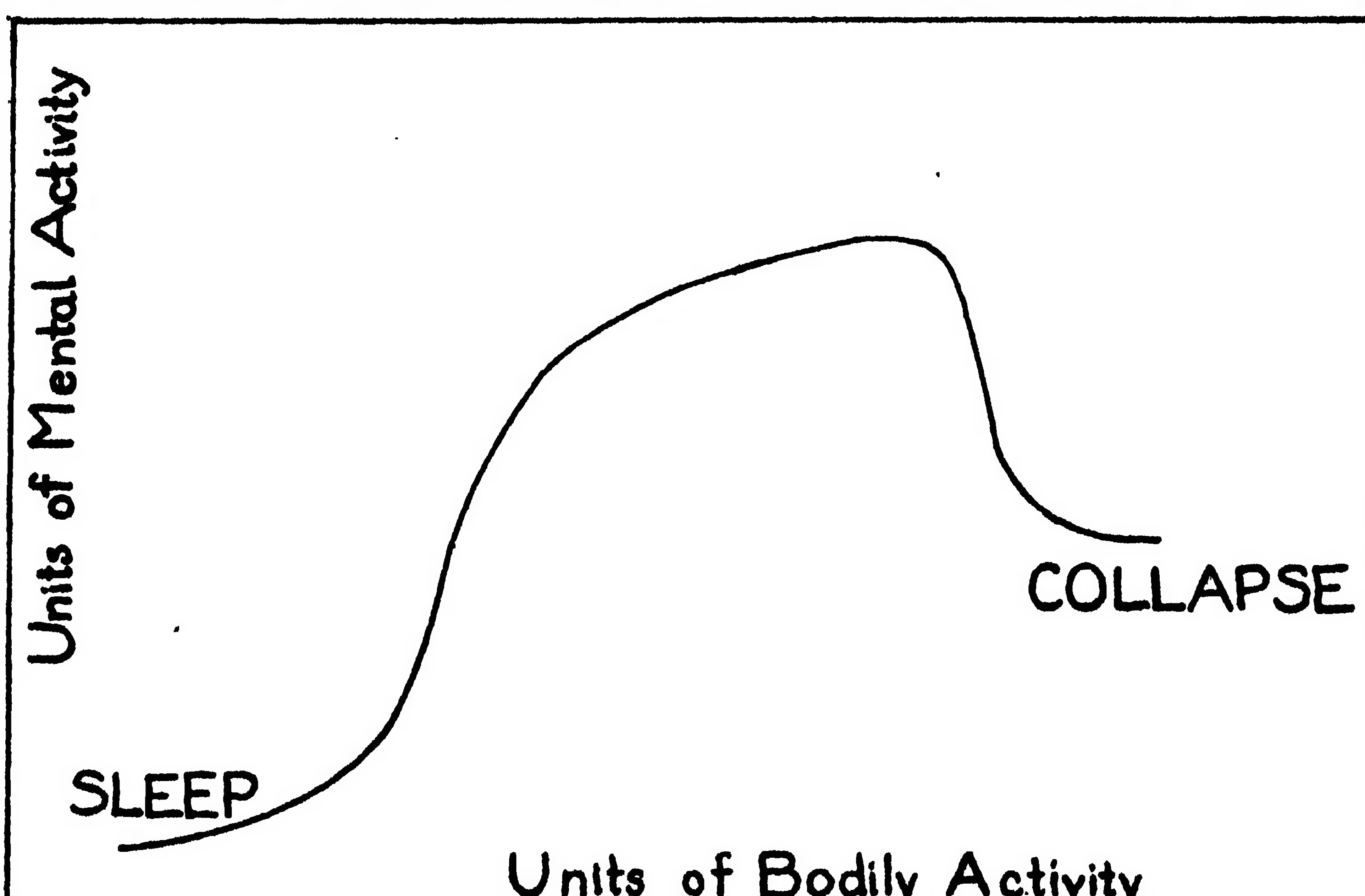
Let us state the idea in another way. The experience of a sound is dependent upon the excitation occasioned by an external energy source *plus* internal "energy" derived from the backlash of excitation from the muscles. We might go on to say that the experience can be heightened even further by increased muscular effort. This was exactly what occurred in certain experiments, where increased tension lowered sensory thresholds, shortened learning time and even compensated for lowered vital condition due to sleep-loss and fatigue.

We shall not stop here to detail how the summation of externally and internally developed energies might take place. For our purposes it is simpler to speak of the muscular processes as aiding

up to a certain point those higher nervous processes which we call mental, then affecting their disintegration in states of excessive reactivity. That these facilitative and inhibitory effects act to prepare for a given level of response adjustment rather than to complete an isolated neural circuit is an inference based partially upon the study of the spread of neuromuscular excitation, partially on the knowledge that the extrapyramidal (tonic) motor system anticipates and sets the stage for reaction of the pyramidal (phasic) motor system and partially upon the fact that no highly specific pattern of supporting tension is apparently present during mental work.

The dependence of effective mental action upon the character of the postural substrate has important general implications. While final confirmation is far from complete, it now looks as if this relation could be expressed by a function similar to that shown in the graph. This indicates that organic input increments (which includes the autonomic processes as well as the associated skeletal tensions) support increasingly effective performance up to a certain point, after which more excessive reactivity is accompanied by performance of decreased effectiveness. Performance levels maintained at the beginning of the curve would be akin to sleep whereas those at the end of the curve would represent complete mental and emotional collapse, though the height of performance attained and the range of reactivity covered would vary considerably with individuals. In all cases, however, it should be possible to describe as the most efficient working level, a point on the graph beyond which increments in organic input produce decreasing gains in performance.

If effective performance is judged as that occurring within the most efficient working limits of the average human machine, great will be the striving to keep within the proscribed bounds. Because



THEORETICAL RELATION BETWEEN THE EFFECTIVENESS OF "MENTAL" ACTIVITY AND THE QUANTITY OF SUPPORTING BODILY ACTIVITY.

of factors making for individual differences, one man may be able to work below the most efficient level of his individual curve and still attain the average proscribed efficiency for a given task. More serious will be the cases of men who must work beyond the efficient level of their individual curves in order to attain performance equivalent to that which superior machines can accomplish with less energy expenditure. Their systems are definitely overloaded and unless remedial procedures are instituted they frequently become headed for mental disorder and collapse.

It is not surprising that people who are fortunate enough to be absorbed in interesting work are inclined to give little attention to the drain being made upon their postural energies until their mental health is in danger of being impaired. This, however, is not the best time to attack a bad habit. The farther out of equilibrium that a reaction swings, the more difficult it is to reestablish balance. Our studies of the relationship between mental and muscular activity have brought us into contact with a large number of debilitated professional people. The question most frequently asked is "How can I make myself relax?" In most cases such people are working beyond their most efficient level of energy expenditure. The autonomic-glandular processes are beginning to contribute heavily in the mobilization of organic resource. These processes are more difficult to relax away and tensions which were apparently essential for handling certain difficult situations begin to persist after the need is discharged. The differential relaxation normally attained in reading a book gives place to a posture involving uselessly wide-spread bodily activity. The individual is often kept awake at night due to residual hypertension or related visceral disorders. Shortly there occurs changes in his mental attitudes and behavior indicating that he is losing his grip on a rational, highly integrated adjustment to his situation. He becomes irritable, peevish, emotionally unstable. His friends begin to avoid him and he himself may begin to think he is losing his mind. Then comes a conflict situation which taxes his power of adjustment as never before and he makes a critical failure. The various types of disorders which accompany this final state of collapse are well known to the psychiatrist. He, however, is like a captain called upon the bridge after the ship has started to sink. For just as a boat loaded beyond its "plimsoll mark" will not bear up through a rough passage, so an already overloaded human machine is likely to go down in trying to meet a difficult emergency.

It is proof of yet untouched areas that we know scarcely nothing about the mechanisms involved in the neuroses. Apparently two general factors contribute to the ability to withstand breakdown under load. One might be called the drive "libido" or potential bodily energies which can be mobilized for action. The other factor refers to the directional control, "ego" or degree of inhibition and coordination exerted by the higher nervous centers over the basic organic resources. The interrelation of these two factors will probably help to explain why some human machines react under load by regression to behavior characteristics of a lower than average energy level while others progress to the abnormal behavior of the hyper-active level. The basic answer lies of course in further research.

Meanwhile, what can be done for a person who is constitutionally more tense and "nervous" than the average of his fellows? For one thing, such individuals can seek lines of endeavor which will not

tend to emphasize this condition. Any work which sets an impossible pace or one which can not be mastered except by the greatest effort should be avoided. In case, however, that the individual is well launched on a difficult career and enjoys it in spite of its demands, he should take heart. A man of superior intelligence should not be urged to begin carrying a hod, simply because he experiences difficulty in meeting complicated situations with the calmness of some other people engaged in similar performance. Habituation to such work should produce some reduction in tension. Many individuals have acquired ease in their dealings only as the result of years of experience. It is only those whose "years of experience" have produced counter effects that are a serious problem. If each day's work is more exhausting, if each new situation is handled less adequately than the last, if each night's insomnia indicates the presence of more residual hyper-tension than the one before, then there is need for some drastic change in the organization of one's life. Small wonder that many individuals in such plight have subscribed to all manner of quack and nostrum. We can only wish that these had done as much good as they have harm.

There is one very bright hope for those who find themselves habitually tense and excitable. If such people can acquire inhibitory control and coordination of their activities in the face of a hyperactive postural substrate they may come actually to excel more phlegmatic individuals; if they can learn to harness their machine, it should produce not only *more* intellectual goods but also goods of *finer quality* than a sluggish machine. Many of our most successful men are dynamos of neuromuscular energy behind their surface of exterior calm. They are apparently separated from certain inmates of our state asylums by a rather narrow line. They have learned to coordinate and control rather than to dissipate and abuse. And the majority of them will say that they did this thing by themselves, not by the applications of a rubbing doctor.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

HARNESSING THE SUN'S ENERGY

The dream of converting sunshine cheaply into some form of practical power, such as electricity, is undoubtedly closer to realization than the release of the supposed power within the atom.

The earth's imports of solar energy are about all that it receives from outer space that is of any consequence. Immense quantities of energy are received. During the three months of greatest sunshine in the temperate zone, an acre of land receives directly from the sun an amount of heat equivalent to the burning of approximately 250 tons of high-grade coal.

Only a minute portion of this energy is captured and converted by plants growing on the land—some two or three tenths of one per cent. Our modern industrial civilization is possible only because inefficiently, but in impressive quantity, the past ages stored up sunshine in coal, oil and gas.

The search for more efficient solar energy utilization is being energized by Dr. Godfrey Lowell Cabot's gift to the Massachusetts Institute of Technology. Professors and students will be spreading a research net for new facts and applications.

The program has three directions: (1) Means for utilizing solar heat to operate engines to deliver mechanical power. (2) The possibility of converting solar radiation into electrical energy. (3) Chemical conversion of sunlight into forms available for work.

Mirrors might concentrate the sunshine and feed it to engines operating on small temperature range at low upper temperature, with small first cost and low maintenance.

Hope for electricity directly from sunlight lies in improving the low efficiency of vacuum or gas-filled photoelectric cells, thermopiles and boundary-layer apparatus, such as the copper-copper oxide cell.

There is possibility of eventually discovering chemical compounds that can absorb sunshine and convert it economically into stored energy.

RUBBER BEARINGS IN UNDER-WATER WORK

Add rubber to your list of unusual materials now being used for surfaces of bearings. Copper, lead, babbitt metal, rarer cadmium and indium, even silver, are the best known members of the bearing family, for they all possess special properties of toughness, long wear, corrosion resistance or other desired characteristics. Flexible, yielding rubber seems a strange addition to this bearing family.

And yet, when you study the places where rubber bearings find usefulness the application of rubber is not too surprising. Pumping systems for drinking water and many solutions used in the preparation of foodstuffs or beverages comprise one application. A few others would include: high-speed motor boats, underwater marine work, hydraulic turbines, centrifugal pumps, agitators, washing machines and domestic and industrial liquid-handling equipment.

Secret of rubber's usefulness as a good bearing material is its ability to suffer

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

slight displacements and yet keep a tight fit. Thus a grain of sand or other hard particle only makes the rubber surface give and does not force the particle into the axle, or bearing surface.

As reported to the Institution of Mechanical Engineers in London by Sydney A. Brazier and W. Holland Bowyer, water or other fluid, and not oil is the lubricant with rubber bearings. A series of slots are provided in the bearing and the fluid passes, rather freely, through these interstices so that it can wash out dirt particles and also remove heat, for rubber's heat conductivity is so low that this factor is a problem in the use of these bearings.

As described in *Mechanical Engineering* the use of rubber entails no sacrifice in bearing life, for oftentimes a rubber bearing will outwear a metal bearing under the same service conditions.

"SHAPE" OF RAINSTORMS AND THEIR EFFECTS

Rainstorms have shape and structure, and these determine to a large extent their effects for both good and ill. This has long been realized in a general way, but it has not been until lately that even an approximation of close study of these highly important meteorological phenomena has been possible.

At the recent national meeting of the American Meteorological Society, the subject was discussed by representatives of two different parts of the U. S. Department of Agriculture: Dr. Merrill Bernard, of the U. S. Weather Bureau, and Dr. C. W. Thornthwaite, of the Soil Conservation Service.

One of the principal handicaps in the more minute study of rainstorm shape and structure has been the relatively wide spacing of observation points. The raingages and other instruments necessary for obtaining data have been located at cities scores or even hundreds of miles apart, with scattered supplementary stations maintained in smaller places by volunteer observers. Records have been taken, as a rule, only once or twice a day, so that a cloudburst of an inch in an hour might appear on the record as a 24-hour precipitation.

However, with the simultaneous advent of depression and drought, with relief consequently necessary for many farmers, the ill winds have been taxed for at least a modicum of scientific good. Weather-recording set-ups have been established in a thick network over a whole river watershed in Ohio, with a station kept by an instructed farmer about every four miles. Records can be taken every half-hour or even every fifteen minutes.

It has thereby become possible, after assembling and digesting the vast masses of data in central computing offices, to learn where the rain has fallen thickest and for how long. The extent and movements of the rainiest and the "driest" parts of a rainstorm have been traced, and quantitative figures of runoff, soil erosion, local floods and other long-desired but hitherto unavailable data have been obtained.

SOYBEAN VARNISHES

It is just a bit more than a year now since active work on most of the projects at the government's Soybean Laboratory at the University of Illinois got under way. And in that year America has been diligently trying to learn about soybeans.

Thirty-six different varnishes containing 100 per cent. soybean for their oil content have been developed and are now undergoing exposure tests to determine their aging properties, according to Dr. Henry G. Knight, of the U. S. Bureau of Chemistry and Soils, reporting in *Industrial and Engineering Chemistry*.

The acid, alkali and water resistance of many of these oils is excellent, adds Dr. Knight, who urges that some of them

appear to justify their immediate use for certain purposes. All that needs to be realized by the user in applying the new soybean varnishes is that their drying time is not as rapid as the super-quick lacquers which are so popular for many uses.

The work of the soybean laboratory is, in many ways, a race with increased production of soybeans by the American farmers. In 1926 only 2,646,000 pounds of soybean oil were crushed. In 1937 the crush will be near 200,000,000 pounds when final figures are compiled.

Soybean oil, oilmeal, soybean flour and other food stuffs are some of the products of the soybean tree. Among its industrial and food uses are: paints, enamels, varnishes, printing ink, linoleum, plastics, shortenings, margarine, foundry cores, livestock foods, flour, soy sauce, dietetic foods, infant foods and beverages. From the protein content of soybeans a leading automobile manufacturer is now making a synthetic fiber quite comparable with the Italian trick of using the protein in milk casein for the same purpose.

VITAMIN A IN DAILY DIET

Doctors and nutritionists tell you to drink plenty of milk and eat plenty of fresh fruits and vegetables every day in order, among other things, to insure getting enough vitamins. But maybe you have wondered how much is plenty. Having learned to count your calories, perhaps you would like to be able to count your vitamins instead of guessing at them.

Vitamins are measured by what are called "units," a unit being the amount that will produce a certain definite effect in a laboratory animal that has been deprived of the particular vitamin. As vitamin chemistry has developed, scientists have been able to define units in more mathematical terms, which has greatly simplified standardization and dosage of vitamin products. The International Unit of Vitamin A, for example, is defined as the "growth-promoting activity of 0.0006 milligrams of crystalline beta carotene." Carotene is the stuff from which the body makes vitamin A.

An adult should eat at least 3,000 vitamin A units daily in order to remain healthy, avoid night blindness and be better able to withstand infection. More than 3,000 is desirable.

You can get 670 units of the daily 3,000, says the National Dairy Council, from a generous, six-to-quart-size serving of ice cream, 700 units from an ounce of cheese, 1,040 units from a pint of milk and 1,600 units from one and one half ounces or about three tablespoons of butter.

Getting over to other foods, you get 1,000 units of vitamin A from one ounce of raw carrots; 3,000 units from an ounce of liver; 3,000 from an ounce of spinach; 700 units from an ounce of squash; 800 units from an ounce of fresh prunes; 1,000 units from an ounce of eggs; and from good old cod-liver oil, 8,280 units from one teaspoonful.

THE HOSPITAL FOR MENTAL DISEASES IN VIENNA

Few scientific discoveries have the dramatic thrill for mankind that is possessed by certain epoch-making medical discoveries. The story of lives saved by insulin as a cure for diabetes, by liver for pernicious anemia, and, most recently, by insulin again as a cure for dementia precox have the heart-touching appeal of modern miracles.

Among these medical wonders is the tale of the conquest of paresis.

Paresis is particularly tragic because it attacks men in the prime of life, robbing them of health, happiness and sanity itself and leaving them to a slow horrible death. It was once called Officer's Dis-

ease because it would develop in those army men in the higher ranks who remained for a long time in the service. Enlisted men who left the army after their service was done, did not come under the observation of army physicians after the paresis had had time to develop.

First hint of the cure came also from the experience of the army. For it was observed that men returned from the tropics did not fall victims to this disease. It was at the Hospital for Mental Diseases in Vienna that Professor Wagner von Jauregg discovered that the tropical fever malaria would kill the organism responsible for paresis.

As a result of this discovery, just about a third of the formerly doomed paresis patients, as treated with the malaria therapy in the United States, may now get well and go home again.

Recently the Vienna hospital celebrated its 30th anniversary—now, as at its founding, one of the most modern institutions of its kind. Segregation of patients according to their condition, social rooms, theaters and modern equipment and treatment make the outlook for the patient favorable. A special wing for alcoholic cases exclusively and a bureau for the supervision of alcoholic outpatients are innovations.

The Vienna hospital reviews an enviable past. What will the future hold?

PREVENTABLE SMALLPOX

If there is any disease that it is almost criminal to have, that disease is smallpox. Ever since the time of Jenner, the simple process of vaccination prevents it at trivial cost and inconvenience.

America's largest city, New York, has been entirely free of smallpox since 1932 and no one has died of that disease there since 1926. That can hardly be said about any other human ill. But the United States is not free from smallpox. In fact, this disease is on the increase. There were 11,806 cases in 1937 as compared with 7,844 the year before, according to Metropolitan Life Insurance Company figures.

This is disheartening to medical authorities. A few years ago it seemed that the disease was at last coming under control and would be eliminated as a major health problem. Fortunately, the form of smallpox prevailing in the United States is mostly the mild, nonvirulent type which causes relatively few deaths. But this mildness may change to a more deadly form, killing hundreds or thousands before vaccination stops the march of a serious epidemic.

It is not the congested areas of the East that constitute smallpox's stronghold. The record of the past five years shows only 256 cases in eight crowded eastern states, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland. There were 14,203 cases in eight less populous states in the opposite corner of the U. S. A.—Washington, Oregon, Idaho, Montana, Wyoming, North and South Dakota and Nebraska. The contrast was one case per million of population as against 428 cases per million.

This difference is merely a matter of how widely vaccination is practiced. For smallpox flourishes in every clime and country if given the chance. Evidently only a devastating epidemic of the more dangerous kind of smallpox will teach a costly lesson where vaccination is lax.

SCHOOL BOOKS AND DISEASE GERMS

Every so often in some community comes up the question of disease germs being spread by school books. This is only natural, since books handled by patients having tuberculosis, scarlet fever, diphtheria, meningitis, infantile paralysis and kindred diseases are more than likely to get some of the germs on them either from the patient's breath in sneezing or coughing or from his hands.

A pretty clean bill for ordinary school books, however, and some recommenda-

tions on books in general are now presented by Arthur H. Bryan, of the science department of Baltimore City College. He collected pages from very old and from newer school books, most of which had been recently used by students, cut up the pages, soaked them and shook them in sterile water for from 15 minutes to one hour, and then transferred some of the water to germ growth media to get some idea of how many germs actually had been on the pages of the books.

Ordinary school books, surprisingly enough, showed very few germs and those mostly of a harmless variety. Books that are not too old or dilapidated, he concluded, are not serious carriers of infectious diseases. School books that are kept for some time before being redistributed do not seem to have many living disease germs on their pages. Old books with visible dirt and grime smeared over their pages are capable of harboring many more disease germs than clean or new school books.

Mr. Bryan recommends that old school books which are frequently exchanged should be opened up and sunned for several hours. Books used by sick children should not be handed out to other students immediately (most germs die or lose their virulence if kept away from body tissues for a while). Books which are dilapidated, out of date and filthy with grime should be destroyed. Books coming back from quarantined homes should be destroyed or held for several months before redistribution.

WORRY AND TOOTH DECAY

Worry makes the teeth decay. That may seem like a far-fetched statement, but it appears to be a logical enough conclusion from a recent study at Cornell University by Drs. A. L. Winsor and Barney Korchin.

Upsetting the dicta of older physiology textbooks that the saliva in your mouth is naturally alkaline, the experiments of these investigators, carried on over a year, indicate that instead the saliva is naturally somewhat acid.

When the flow is increased, as it is by chewing or by appetite, this acid content becomes diluted—the saliva is less acid.

But remember how your mouth feels when you worry or are angry? It is dry. Your tongue "cleaves" to the roof of your mouth. That means that the normal flow of saliva is cut down, and with the lessening of the flow the acid content is increased.

The degree of acid remains proportional to the flow whether your mouth waters from the odor of broiling beefsteak, or the smell of pickles, or merely from chewing on a hunk of bubble gum, these investigators found. The greater the flow, the less the acid content.

But after prolonged mental activity, when you are very tired, or after you have been asleep, your saliva is more acid, the Cornell investigators found. The secretion that accumulates in the glands during rest periods is less acid if the previous flow was plentiful.

So great is the effect of making the mouth water that the secretion can be changed from acid to alkaline in less than one minute, they found.

"A possible relation between these data and the recently reported studies of dental decay and nervous upset was suggested," conclude Drs. Winsor and Korchin.

THE EMOTIONAL BREAKDOWN OF A CAT

It may seem a long step, psychologically, from a cat whimpering in a box to a young student who throws down his books and bursts into an emotional storm. But is it? Let us look further into the story of Tom the cat as told by Dr. Harry W. Karn, of the University of Pittsburgh, in the current issue of the *Journal of Experimental Psychology*.

Tom was a willing, docile cat. Being a laboratory cat, he had lessons to learn,

but he undertook them readily. The task, suited to his feline powers, was this: He must run down a center alley of a maze box, turn right around a hollow square to his starting point, repeat this maneuver a second time, and then follow a similar course to the left twice—twice right and then twice left. A reward awaited after each correct turn.

The second turn to the right was always the hardest for Tom. At one time during the early stages of his education, he fell into the way of turning right, left, left, right, and he persisted in this wrong habit for about 75 trials. Gradually he learned the correct pattern of right, right, left, left, however, and in 230 trials he built up an accuracy of 90 per cent. He was a grade B pupil.

But his teachers wanted to see whether he couldn't earn an A. So they persisted. At the second turn in the 232nd trial a radical change came over Tom. He hesitated much longer than usual at the turn and then jumped and raced around. After that he refused to enter the box. He scratched and clawed at experimenter and maze. He would not work. And he howled.

Only twice in 32 trials did he make the right turns. He went back to that old wrong pattern of right, left, left, right.

What had got into Tom? Whatever it is, psychologists would like to know, because we have seen the same thing happen to many a human Thomas. Willing, docile and reasonably successful, up to a certain point, they suddenly fly off the handle; they go back to childish ways of behaving; they strike out at those around them; or, like the cat, they cry.

FOSSIL SNAKES

Snakes are a comparatively new thing under the sun. In the Age of Reptiles, that ended only 50 or 60 million years ago, they were almost unknown. Only the last of the dinosaurs, that lived in Cretaceous times, ever had a chance to see snakes, and those were of the earliest models and probably not numerous at that. At least, their fossils are exceedingly rare to-day.

Data on the relative recency of snakes are included in a new monograph on "Fossil Snakes of North America," written by Charles W. Gilmore, of the U. S. National Museum, and published by the Geological Society of America.

The first snakes were non-poisonous, resembling modern blacksnakes and boas in that respect. Venomous species did not appear, so far as the present record shows, until Upper Miocene time, roughly from 13 to 18 million years ago. First rattlesnakes began buzzing in the geologic period immediately after that, the Pliocene, which lasted from 13 million years ago until the Ice Age began, about a million years back.

The prize specimen in the collection studied by Mr. Gilmore is the practically entire skeleton of a snake embedded in a slab of shale from the Green River formation, in the northern Rockies. Because of the slenderness and fragility of snake bones, it is rare to find well-preserved fossils at all; no skeleton so nearly complete as this has ever been discovered. Technique combining the skills of sculptor and dentist was necessary to free the fine bones from their stone matrix, but it was finally accomplished without mishap. This early invader of the American Eden was a serpent a couple of inches over a yard long. It has been given the scientific name *Boavus Idelmani.*

THE LONGEVITY OF BIG TREES

Honors for greatest age among living things are re-awarded to the Big Trees of western America in a summary study by the late Dr. Hans Molisch, formerly director of the Institute of Plant Physiology, the University of Vienna. Dr.

Molisch's book has just been translated and published in English by an American botanist, Edmund H. Fulling, editor of *The Botanical Review.*

The Big Tree's only close competitor for record length of life, in Dr. Molisch's tabulation, is the baobab tree of Africa, which is given an estimated age of 5,000 years. However, this is only an estimate, whereas the equal age of the Big Tree is backed up by actual counts of annual rings in the trunk.

Next in line come the banyan of India, sacred for having sheltered the Buddha. The identical tree under which Gautama sat when inspiration came to him is still pointed out, and since it has been a holy place during all the centuries, it is quite probable that the tradition is accurate, so that the estimated 3,000-year age of the "bo-tree" is well supported.

Not so well fares the giant cypress of Tule, in Mexico, at which stout Cortez marvelled, and which the famous German traveller, von Humboldt, estimated to be 4,000 years old. "Comparative estimates have indicated, however, that this swamp cypress can scarcely be more than 2,000 years old," says Dr. Molisch; "further proof that estimates alone easily lead to inaccuracies and exaggerations."

Even more drastic scaling-down in estimates had to be made for the age of the great dragon-trees of the Canary Islands, likewise claimed to be the world's oldest. Dr. A. Putter, who studied these trees critically shortly after the World War, would grant the oldest of them no more than 185 years. The claims of 5,000 or 6,000 years, advanced by natives for their trees, Dr. Putter dismissed as trivial, because the same natives "not infrequently do not know their own ages nor those of their children."

OUTLINING THE ROMAN EMPIRE

When ancient Rome was in power, the civilized world knew well enough where the guarded frontiers of Roman empire ran. To-day, it is taking the eye of the camera looking down from an airplane to find obliterated lines of that empire.

Work of mapping the whole Roman Empire was started in 1930 by an international commission of geographers. Since then various countries that control regions of the one-time empire have helped with the problem.

Ruins of old forts and roads and embankments have to be studied by the slow, hard process of excavation. But it is the flying archeologists who have been scouting out the lay of the land for the excavators, and mapping for them the most elusive lines of lost frontiers.

In Syria, a French archeologist, Père R. P. Poidebard, has done much to trace Roman fortifications from Bostra eastward toward the Tigris. His interest in aerial photography goes back to 1926.

Père Poidebard has learned by experience that in this desert country ruins appear and vanish even so far as the sharp eye of the camera is concerned. Not only the season, but time of day and weather conditions affect sighting of phantom ruins.

Early morning and late afternoon light are best for sharpening the shadows and bringing out obscure patterns of ancient handiwork buried lightly in the earth. Yet, the French observer has outwitted the sun on occasion, making hidden ruins visible near midday by the trick of flying low and using the plane wing to shadow the ground. The first time he used this technique, he detected an ancient road leading toward the Tigris River, that previous observers had missed. Once spotted, the ruins are marked on maps, and then the spade expeditions go out, to learn more about the frontier defenses in which ancient Rome put her trust.

FEAR IN AINU WOMEN

The happy savage is not so happy, after all. Jean Jacques Rousseau gave

the world a rosy picture of primitive life. And ever since, the popular notion has persisted that primitive man has no fears and worries. At least, none worth mentioning in the same breath with the city dweller's harassed nerves.

But scientists are finding that primitive man and his wife do fret. Get close enough to some native group, and you may find ugly mental and nervous disorders preying on individuals. What particularly interests the psychiatrist is that a primitive group has its own peculiar forms of mental and nervous abnormality.

A curious fear reaction that besets the Ainu race has been studied lately by three Japanese psychiatrists. Out of 17,500 Ainus, who inhabit Japan's most northerly islands, 111 women were found suffering from abnormal susceptibility to fear. Over half owed their condition to some fright over a snake, in the past.

Whatever caused the trouble—fright at a snake, frog or other creature—the same object would at any time cause the victim to go through a routine of queer behavior. Even mentioning a serpent was enough to start an attack in some women. The terrified Ainu would grow hysterical, fall into a cataleptic fit, reduced for several minutes to automatic and abnormal behavior. In the past, this condition, called imu, was said to be more prevalent than now. Both sexes were affected.

The Japanese doctors conclude that this hysteria, which differs from the usual forms of hysteria found in civilized life, is a primitive form, and even goes back to the prehistoric era of Ainu life.

DIFFICULTIES OF RIVER REGULATION

America is not the only land where ill-advised "improvements" to rivers have brought loss and trouble in their train. Some of the older countries made their mistakes earlier—and have had longer time to be sorry for them.

A clear-cut example is furnished by the wide flood-plain lands of the lower Danube, on the estate of Count Traun, one of the great landholding nobles of Austria. Until the end of the eighteenth century the river floods were allowed their own way on the flatlands. They deposited fertile silt, which made for lush growth of vegetation and rich forests.

Then, early in the nineteenth century, the river was "improved." Its channel was straightened, and levees were built to keep its floods away from a large part of the former overflow lands.

To-day the consequences are tragically evident. The protected lands back of the levees have been stripped of their forest cover, where they had it, and all of the land has been so intensively cultivated that the alluvial soil has been "mined" of its plant nutrient wealth. And of course, no new silt deposits can be brought by the river to renew it.

Between the levees the condition is even worse. The river, in its straightened, narrowed channel, rushes through rapidly. When high water occurs, it boils out into the restricted flood plain that has been left to it. Long since, it carried off the rich surface soil it had once deposited. In its stead, the river now dumps gravel and coarse sand. The land that was once almost tropically luxuriant meadow and swamp forest is now a tortured, sterile desert.

The loss is felt by everybody concerned. The present-day Counts of Traun get less income and have less hunting in the lowland thickets. Their peasant tenants harvest less hay and have less wood to burn. And the impoverished treasury of Austria collects less taxes.

THE WORK OF BEAVERS

By EDWARD R. WARREN
COLORADO SPRINGS, COLO.

In studying the work of beavers even though for the most part in a few localities as I have done for a considerable number of years, many things of special interest are found sometimes quite new, and again, though not especially new, yet worthy of recording. There are two streams some fifteen miles northerly from my home in Colorado Springs—Monument Creek and its tributary, Beaver Creek, where I have studied the beavers more or less continuously since 1913.

Dugmore, in his "Romance of the Beaver," mentions a dam in Newfoundland, where, during high water, the beavers removed part of the crest of the dam, thus forming an opening or spillway through which the water escaped, relieving the pressure on the dam and possibly saving it from destruction. I must confess that I was somewhat sceptical about this, but have since seen an instance where I had little doubt that the beavers had done just that very thing, and not only on one dam but on three successive dams. This was on the 23rd of April, 1926, on Beaver Creek, at a time when the stream was high from melting snows at its head. Here were three dams, one above the other and some distance apart, and each had a gap in it through which the water escaped. This gap was in each of two cases seven feet wide and about a foot deep (Fig. 1). I did not measure it on the other dam, the lower of the two. At this one, on May 14, I found that the opening had been deepened so much that the pond was drained, and remained so for a year or more, when the dam was rebuilt, though somewhat differently from its original form. After the high water had subsided the gaps in the two upper dams were closed and the ponds refilled, maintaining a varying existence for a few years. It seemed to me that these openings must have been purposely made to relieve the pressure on the dams.

Farther up the stream on the same day of April, I found another dam where the stream had broken through, and pushed a tangled mass of the material of the structure out and down. This mass was nine feet long up and down stream and about six feet wide. The opening made by the water was eight and a half feet wide, and was from three to four feet deep. A week later there was no special change, but on the 14th of May I found that some sticks and trash were across the bottom of the gap and the pond was filling a little (Fig. 2). By the 22nd the beavers had built up to within fifteen inches of the top of the dam and there was plenty of water in the pond. Later the dam was built to its former height. A few years after this the dam was again broken, this time near the left end, and never repaired. As new dams were constructed farther upstream I presume that that is where the beavers went.

The spring of 1926 seems to have been a time of catastrophe to the beaver dams on Beaver Creek, for again on the 23rd of April, when I went upstream from the last-mentioned dam I saw still another which had been broken by the high water (Fig. 3). This I did not examine particularly until early in May, when I found an unusual construction. The diagram (Fig. 4) will help to make this clear. The right section of the dam went

FIG. 1. DAM NO. 13, BEAVER CREEK, APRIL 23, 1926. SHOWS THE OPENING OR SPILLWAY IN THE DAM. DAM NO. 14 CAN BE SEEN ABOVE, WITH ITS SPILLWAY SHOWING IN THE UPPER CENTER OF THE PICTURE. DAM NO. 15, WHICH ALSO HAD A SPILLWAY, WAS ABOVE AND DOES NOT SHOW.

directly downstream twenty-four feet to the break, and thirty feet to the left section of the dam that had been forced out by the water and turned around so that it was continuous with the other part. There must have been great pressure to have accomplished this, and it is remarkable that the dam should have held together instead of breaking up and going downstream piecemeal. This is, however, not the only occurrence of the sort that I have seen. A study of the situation here indicated that once the dam extended straight across the stream from the upper end of the portion now extending downstream, and it seemed as if some preceding flood had moved that 24 feet around to the position in which I found it and that the beavers may have then built the dam around from the left end and made a connection. Later on the beavers repaired the gap and filled the pond. In 1929 the pond was finally abandoned.

In October, 1934, I found on Monument Creek something totally unlike any other work of the beaver that I had ever seen. A dam across the stream had been broken, the pond drained, and the shallow stream flowed along near the right bank. At the left bank, a hundred feet above the dam, was a curved embankment, evidently built of mud dug from the bottom and making a pool forty-two inches wide by twelve feet long, and six inches deep and filled with muddy water (Fig. 5, upper left). At this time the lower part of this bank was dark and wet, as if put on the previous night. The greatest width of the bank was four feet. From the lower end of the pool a trail eight feet long went down toward the creek. A burrow was discovered in the bank near the upper end of the pool, and here the beavers were probably living, having constructed the pool rather than abandon the empty pond. In December the pool was frozen solid with no signs of life about it.

On the same day that I found this pool

FIG. 2. ABOVE: THE GAP IN DAM NO. 16, FROM THE POND. THE PICTURE WAS TAKEN ON MAY 14, 1926, AND SHOWS THAT REPAIRING HAD BEGUN. BELOW: THE SAME VIEW TAKEN A WEEK LATER, SHOWING THE PROGRESS OF THE REPAIR WORK.

I came to a dam forming a pond perhaps fifty yards in length. At the left side of the stream, about a hundred feet above the dam, was an indentation or bay. Here there was usually water next the high bank, and bare ground between the water and the stream. The beavers had made a canal starting from the upper side of the bay, curving around through the flooded space, mud banks piled on each side, with a very muddy trail from its end down to the pond. Where I measured it the canal was thirty inches wide, and the water was from nine to fourteen inches deep (Fig. 5, lower left and right). The right bank was continu-

ous from the upper to the lower end of the ditch, but the left one began a few feet from the shore; then there was a bank about ten feet long, then a gap below which a short dam extended out from the shore. From the end of the dam the left bank was continuous to the end of the canal, and approximately parallel to the other side.

Freshly cut stumps were at the upper end, whence a much-used trail crossed to the pond above, cutting across a bend in the stream and entering the next pond above at the left end of its dam. The previous April this dam was broken and the pond empty. In October I found that the dam had been repaired and the pond was full. In the winter neither the canal nor the trail seemed to be in use.

I found an interesting example, of the return of beavers to a pond they were forced to abandon, near Brush Creek, in the Elk Mountains of Colorado. I first saw this pond in August, 1930, when it was full of water. Its supply came from a small stream flowing down a steep mountainside. The pond was irregular in shape, approximately 160 by 340 feet in its dimensions. The north side and west end were formed by a long dam, the south side by a steep hill, whose base the water touched, while the inlet came in at the easterly end. The outlet of the pond was at the westerly end and flowed into Brush Creek a short distance away. This was to the north of the pond at a somewhat lower level. A lodge near one side of the pond was almost hidden by the willows growing about it, which would indicate that it was a rather old structure.

The following August, 1931, I again visited Brush Creek, and as I looked from my camp toward the pond a half mile distant, it presented a very different appearance from that of the previous year. Instead of appearing to contain water it had a whitish look, as if empty and dry. This proved to be the case when I visited it in the afternoon. Not a drop of water was in the pond, and the clay bottom was a network of cracks. The explanation of the lack of water was quite simple. The inlet derived its sup-

FIG. 3. THE GAP IN DAM NO. 18, BEAVER CREEK, APRIL 29, 1926, SHOWING WATER RUSHING THROUGH.

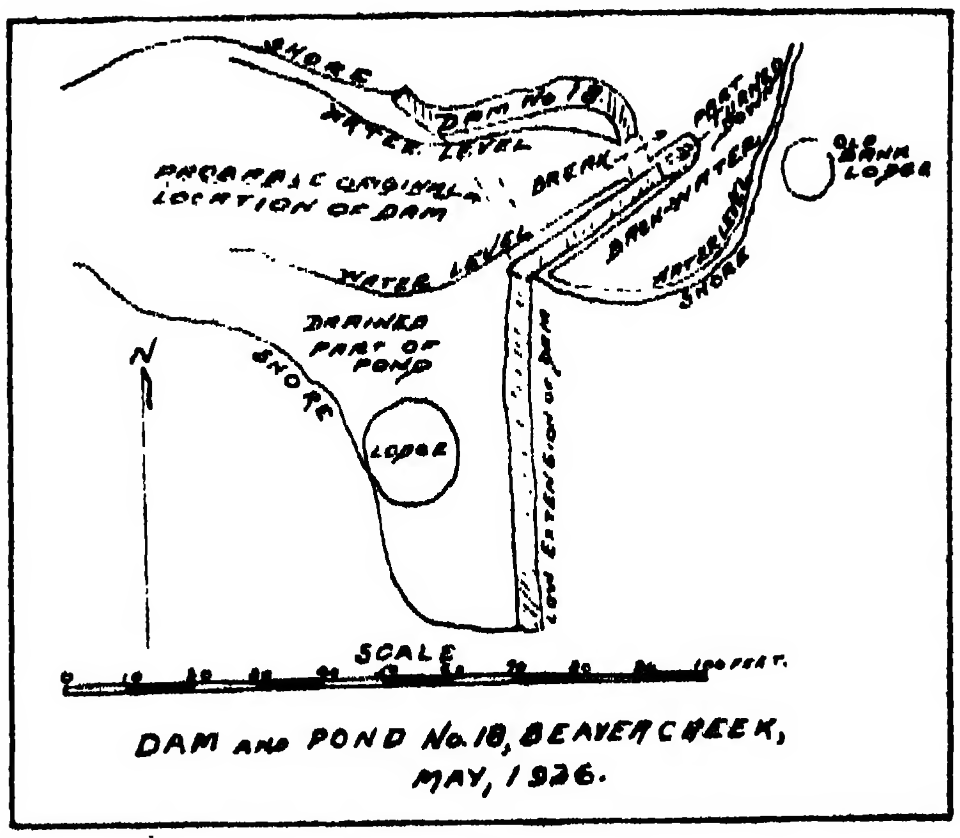


FIG. 4

ply of water from the winter's snow. The snowfall of the winter of 1930–31 had been unusually light, and consequently the stream had failed. The pond received no water, was presumably emptied by leakage about the dam, and dried up. I suppose the inhabitants moved to the creek and lived in the banks.

The house was eight feet high above the pond bottom and had seven entrance holes. The base measured about twenty-six by forty-five feet.

My third visit was made in August, 1932, and as I looked toward the pond from camp I could see that it was full once more. The usual heavy snowfall had come during the winter of 1931–32, and now there was plenty of water in the inlet. I visited the pond in the afternoon and found that the beavers had moved back, and had evidently resumed their usual routine of living. The willows about the pond had grown very much, and I found it impossible to go along the top of the dam because of their luxuriant growth.

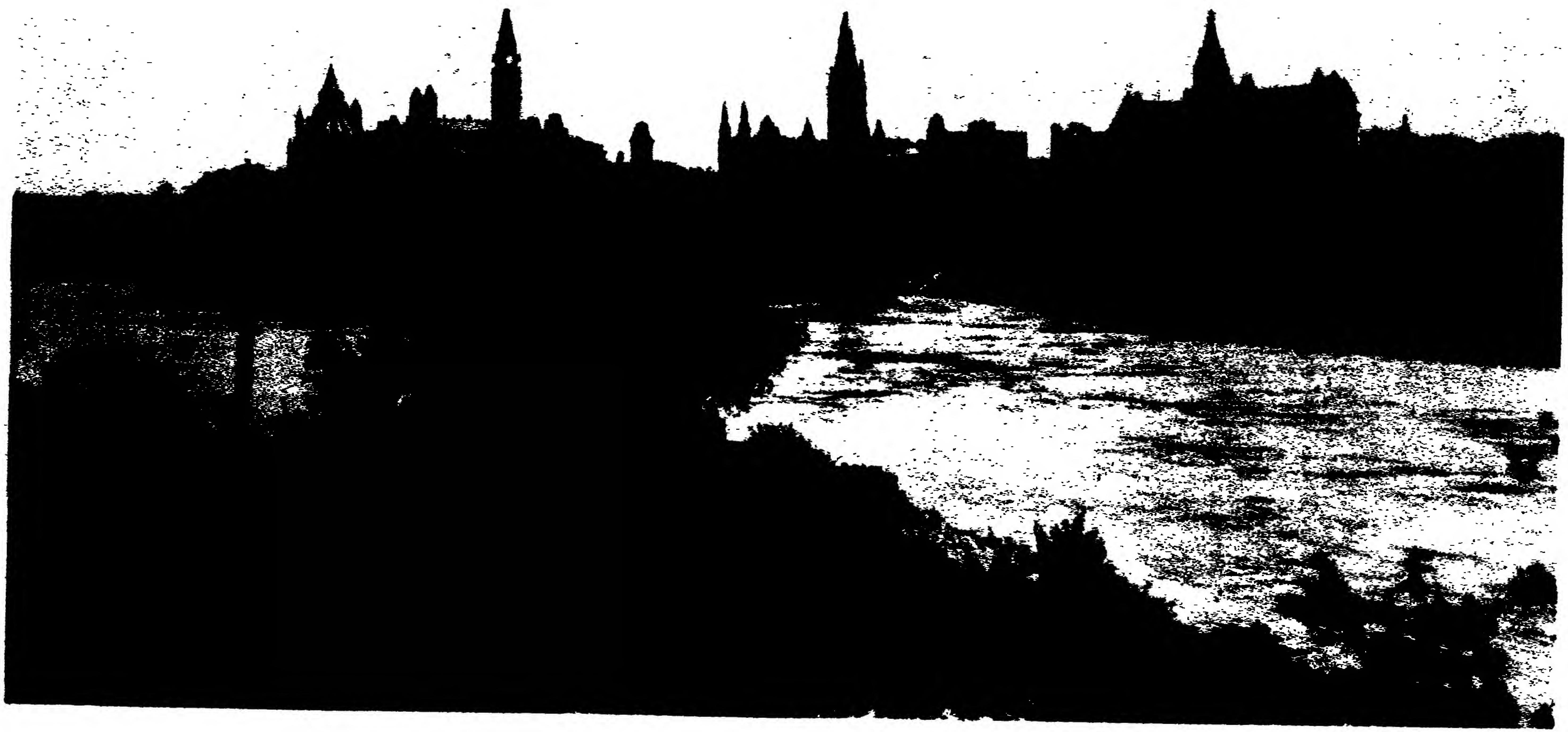
It seems to have been a rather popular notion that beavers build their dams with an upstream curve in order to better resist the force of the current. My own observations show this to be a mistaken idea, and that the curvature of the dam is more likely to be downstream than up. Of twenty-eight dams on Monument and Beaver Creeks whose

FIG. 5. UPPER LEFT: THE POOL FROM THE UPPER END. OCTOBER 24, 1934. LOWER LEFT: THE CANAL FROM BELOW. OCTOBER 24, 1934. RIGHT: THE CANAL FROM THE UPPER END.

curvature I noted, five had an upstream curve, eighteen curved downstream. Five others curved both ways. All told, seventy-seven dams were examined, many of the shorter ones were built straight across the stream, and a few were difficult to classify.

Floods may wreak wholesale destruction on a beaver colony. On Beaver Creek, between the date of my first visit, November 6, 1925, and up to May 28, 1929, I had found seventy-eight dams and ponds which were in use at one time or another during this period. In the winter of 1928–29 I found forty-five ponds were in use. At the head of Beaver Creek, some five miles above the uppermost beaver ponds, are six artificial ponds known as Carrol Lakes. On the 25th of July, 1929, an unusually heavy rainstorm occurred above the lakes, and such a volume of water flowed into them that three of the smaller dams were broken and another partially destroyed. The flood came down through the beaver colonies about nine o'clock at night, and destroyed every dam on the stream.

The owner of the land went to the stream the next morning to inspect the damage, when the water was still very high. He told me that he saw beavers swimming and trying to make their way against the current until they were exhausted and had barely enough strength left to get ashore. He thought a good many beavers must have been killed by the flood. Very possibly some were drowned in their burrows, caught before they could escape.



PARLIAMENT BUILDINGS IN OTTAWA, ONTARIO, FROM THE QUEBEC SIDE

THE PROGRESS OF SCIENCE

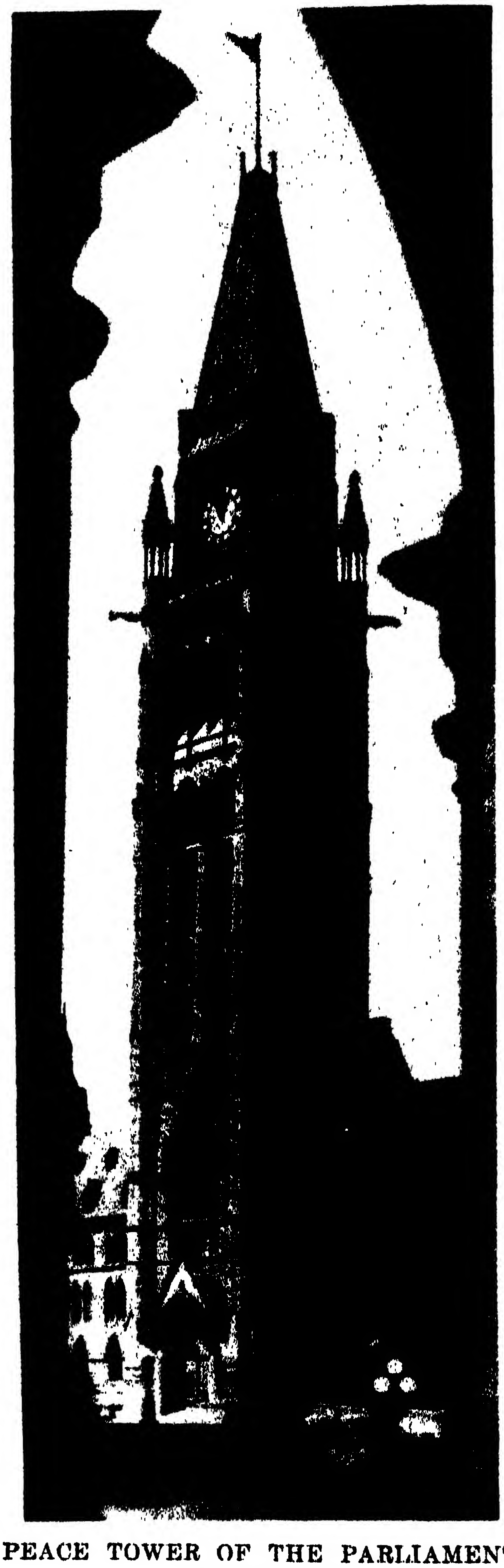
THE OTTAWA MEETING

WITH a registration of 1,104 scientists and visitors, the Ottawa meeting of the American Association for the Advancement of Science, from June 27 to July 2, became the third largest summer meeting of the association. Only the Chicago meeting, held during the Century of Progress Exposition in 1933, and the joint meeting of the association and its Pacific Division, held in Berkeley, California, in 1934, were larger.

Approximately one hundred different scientific sessions were held during the meeting at Ottawa, and approximately five hundred papers were presented, about two thirds of them by Canadian scientists. No distinction was made, however, between scientists residing in Canada and those residing in the United States, for the association is truly American in the broad sense of the word. Perhaps the most important characteristic of the meeting was its entire freedom from any national considerations except in so far as the subjects treated were geographical in nature. The scientists of Ottawa were simply the hosts of the meeting, as the scientists of any city in the United States might have been. That a large part of the papers presented were by Canadian scientists was due partly to the fact that on the whole the Canadians did not have so great distances to travel, and partly to the fact that in Ottawa, the capital of Canada, there are many scientists in the technical bureaus of the government. For the same reasons of convenience the registrations of scientists from states near the Canadian border were much greater than from those that were more remote.

All general discussions at Ottawa of the benefits of science were in terms of humanity as a whole rather than in terms of any special political units. Some of the most important programs of the meeting emphasized that science is, or at least should be, above all considerations of national boundaries, races, languages and creeds. For example, the Science and Society program included papers on such subjects as "World Standards of Living," "World Natural Resources," "The Botanical Sciences and the Future" and "Physics and the Future." In the program of the Section on Chemistry there were papers on such subjects as "Medical Biochemistry" and "The Applications of Isotopes to Biochemical Problems." In all these discussions there was no national or sectional secrecy, but a world outlook; no restrictions by copyrights or patents, but pride in generous contributions to the welfare of humanity. A disturbed world needs many more international meetings in which nationalities and races and creeds sink into insignificance in the presence of larger objectives. Can it be that science because of its biological teachings of the universal brotherhood of man, the objectivity of all its methods and the unselfishness of its aims can inspire humanity with a spirit of productive cooperation instead of destructive conflict? If it can it may in this way be of greater service to mankind than will be all its remarkable technological applications.

There were, of course, programs at the Ottawa meeting which were geographic in character or limited in application. For example, the Section on the Zoological Sciences organized and presented a program on the migrations of the salmon which spawn in North American streams and rivers. After hatching they soon descend to the sea, where they spend all their lives until, guided by some strange influence, they return to the localities of their birth to produce a new generation and to die. The program of the Section on Engineering contained a paper on the collapse last winter of the Falls-View Bridge at Niagara Falls, another on gold mining in Canada and, for variety, another on flying boats. The Section on Historical and Philological Sciences presented a program of a com-



PEACE TOWER OF THE PARLIAMENT BUILDINGS

prehensive history of Canadian science, which if published will be of great value in the future to all who are interested in the growth of science in Canada. The Section on the Medical Sciences presented a symposium, all by Canadian speakers, on "Bacillus Calmette-Guérin," which is the organism from which is produced a vaccine against tuberculosis. The Section on Geology and Geography had an extensive and excellent program built up around such general topics as the geographical characteristics of certain parts of Canada, the mineral industries of Canada, very ancient Canadian rock formations and their economic significance and such geographic problems as raising crops north of sixty degrees of latitude. The entomologists and foresters recognized the eternal struggle between insects and other forms of life, particularly man, in their symposium on "The Relation of Insects to Forest Conservation." Several sections and societies joined in a symposium on "The Genetics of Pathogenic Organisms," which included discussions of the genetics of viruses, protozoa and bacteria.

There were programs of quite different types by the sections on anthropology, psychology and education. The astronomers, as usual, concerned themselves with objects so far away that light comes from them to us only in the course of thousands of years. But their programs illustrate the fact that the fundamental unities which science discovers include the universe beyond our earth and our solar system. And all this diversity of subject-matter, presented at one place and at one time, with each part being influenced by every other part, illustrates the broad interests of the association and the unparalleled opportunities it has for serving science and society.

F. R. Moulton,
Permanent Secretary

JOHN JACOB ABEL

THE death of Professor John J. Abel on May 24 ended one of the most productive, exemplary and successful lives in the modern scientific world. As he had hoped, he died as did his revered teacher, Oswald Schmiedeberg, "in harness." Busily working in his laboratory until shortly before his last illness, death came suddenly from a coronary occlusion during his convalescence from a mild attack of pneumonia.

John Jacob Abel was born near Cleveland on May 19, 1857. At an early age he showed a keen desire for learning and at nineteen entered the University of Michigan from which he was graduated with the degree of Ph.B. in 1883. His college work was interrupted for three years during which he taught mathematics, physics and chemistry and Latin in high school. Anticipating what is now a fundamental precept of medical education, he was one of the few medical men of his day to submit himself to a prolonged training in the fundamental disciplines. He spent nine years in intensive studies in physiology, chemistry, biochemistry, pharmacology and medicine under such leaders of European science as Carl Ludwig, Schmiedeberg, von Nencki and Hoppe-Seyler. He received the M.D. degree in 1888 from the University of Strasburg and, while still an assistant in Schmiedeberg's Institute at Strassburg, he was called to his Alma Mater in 1891 as professor of materia medica and therapeutics (a title equivalent to that of professor of pharmacology). He remained at Michigan about two years and in 1893 accepted the chair of pharmacology at the Johns Hopkins, where he remained until his retirement in 1932.

His investigations, which covered a wide variety of subjects,[1] early brought him recognition both here and in Europe. He was dean of American pharmacology not only by virtue of his status as an investigator but because of his scholarly and kindly personality. He was the recipient of numerous medals and prizes. Universities both here and abroad awarded him honorary degrees. He held membership in many learned societies and was an honorary member of several foreign scientific societies and academies. Only a few days before his death he received news of his election as a foreign member in the Royal Society of London, an honor awarded only for the highest scientific achievements to persons outside the British Empire. Not least among his contributions to the advancement of the biological sciences was the founding of the *Journal of Biological Chemistry* with the late Dr. Christian A. Herter in 1905, and the *Journal of Pharmacology and Experimental Therapeutics* in 1908. He was also one of the founders of the American Society of Pharmacology and Experimental Therapeutics and was its first president. His sphere of influence was wide, and among his most devoted friends and admirers were not only his pupils but others whom he helped or advised either in their research work or personal matters.

In his scientific work Professor Abel was consciously a pioneer. Having opened a new path, he was content to leave its filling and paving to others. Attractive problems to him were those where knowledge was scant and where progress was made not by the application of accepted techniques, but by ingenuity and resourcefulness. His apparatus for vividialysis, colloquially known as the "artificial knidney," is a case in point. By means of this apparatus he was the first to demonstrate the existence of amino acids in the circulating blood. For the most part, his work was centered around the isolation, as chemical entities, of physiologically important substances both of plant and animal origin. The

[1] For a more detailed account of Professor Abel's investigations and early life see this Journal for 1932 (Vol. 34, p. 182).

PROFESSOR JOHN JACOB ABEL

FROM A PORTRAIT PAINTED BY MR. GRIFFITH COALE IN 1918 AND PRESENTED TO THE JOHNS HOPKINS UNIVERSITY BY A GROUP OF DR. ABEL'S FRIENDS. THE PORTRAIT NOW HANGS IN THE WELCH MEMORIAL LIBRARY.

crystallization of the pancreatic hormone, insulin, and the isolation of epinephrine as a monobenzoyl derivative are perhaps the most important of his contributions to our knowledge of the chemical nature of tissue constituents. He frequently expressed his especial delight in the exact nature of the knowledge afforded by pure chemistry. And yet he was not afraid to enter those fields of biology where the dynamic nature of the processes, coupled with imperfect techniques, make the path of the scientific wayfarer tedious and treacherous. As late in life as his seventy-fifth year, he welcomed his retirement from active academic service as permitting his undivided attention to his investigations. It is characteristic that, at an age when the average investigator retires to a life of leisure or at most devotes his time to an extension of his earlier work, Professor Abel should desert his chemical interests and enter what was for him an essentially new field of investigation. A critical analysis of the data convinced him of the inadequacy of the current belief that the toxin of the tetanus bacillus reaches the central nervous system by traveling along the peripheral nerves. He embarked, therefore, on an extensive series of experiments which were still in progress at the time of his death. He brought to these researches the characteristic enthusiasm and tenacity of purpose which were so inspiring to his associates; and although

it is perhaps too early for a final estimate of these investigations they have already served to re-focus attention on what was regarded as established fact.

During the course of his long career Professor Abel collaborated freely with his assistants and many of his publications bear the name of one or more of his associates. He frequently expressed his enjoyment of such association and the personal charm and the unassuming democratic spirit that he evinced in the daily contact of laboratory life left a lasting impression on the succession of young men who passed through his laboratory. It was in this respect that he was most effective as a teacher. He had a long list of pupils, many of whom have attained distinction and hold professorships here and abroad.

He was, *par excellence,* the investigator. To him successful research was its own reward and he consistently declined opportunities to commercialize his findings. His adherence to such principles was a significant influence in elevating the status of pharmacological research in this country. He freely recognized his errors and had developed a wholesome philosophy toward them. Mistakes were regrettable and to be avoided, but too great a feeling of personal chagrin at their commission indicated to him an exaggerated conception of the contribution any one individual may make to the general fund of scientific knowledge. His attitude toward his work is perhaps best summarized in a statement from Lessing which deeply impressed him as a young man and which he frequently quoted:

PROFESSOR JOHN JACOB ABEL

IN CONVERSATION WITH A FRIEND AT THE BOSTON MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN 1932, WHEN HE GAVE THE ADDRESS OF THE RETIRING PRESIDENT.

Nicht die Wahrheit, in deren Besitz irgend ein Mensch ist, oder zu sein vermeinet, sondern die aufrightige Mühe, die er angewandt hat, hinter die Wahrheit zu kommen, macht den Werth des Menschen. Denn nicht durch den Besitz, sondern durch die Nachforschung der Wahrheit erweitern sich seine Kräfte, worinn allein seine immer wachsende Vollcommenheit bestehet. Der Besitz macht ruhig, träge, stolz.

Wenn Gott in seiner Rechten alle Wahrheit, und in seiner Linken den einzigen immer regen Trieb nach Wahrheit, obschon mit dem Zusatze, nicht immer und ewig zu irren, verschlossen hielte, und spräche zu mir: Wähle! Ich fiele ihm mit Demuth in seine linke, und sagte: Vater gieb! Die reine Wahrheit ist ja doch nur für dich allein!

However brief, no appreciation of Professor Abel would be complete without reference to the important role played in his life by the late Mary Hinman Abel, who died in January of this year. Throughout an association of some sixty years, she was companion and adviser, a devoted wife and mother. She was a woman of remarkable personal accomplishment and charm; the author of several books and numerous articles on diverse topics, editor of the *Journal of Home Economics* and active in the civic affairs of the community. The diversity of her interests, however, did not interfere with her participation in the life of her husband and in her unselfish desire to further the progress of his work in every manner. Jointly, their lives represented the finest fulfilment of the ideals of our civilization.

E. M. K. Geiling
E. A. Evans, Jr.
The University of Chicago

THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

Dr. Vannevar Bush, vice-president and dean of engineering of the Massachusetts Institute of Technology, has been elected president of the Carnegie Institution, and will take office in January. He succeeds Dr. John C. Merriam, who has served as president of the institution for seventeen years.

Dr. Bush is a native of Everett, Mass., the son of the late Reverend R. Perry Bush, for fifty years a clergyman in the vicinity of Boston. He was graduated from Tufts College in 1913, and in 1916 was awarded the degree of doctor of engineering from Harvard University and the Massachusetts Institute of Technology. In 1932 he received the honorary degree of doctor of science from Tufts College, of which he is a trustee.

Dr. Bush joined the faculty of the institute in 1919, as professor of electric power transmission, and was appointed vice-president and dean of the School of Engineering in March, 1932. At the same time he was elected a member of the corporation. Early in his career, Dr. Bush held a position in the test department of the General Electric Company and then returned to Tufts College as an instructor in mathematics, subsequently becoming assistant professor of electrical engineering.

Dr. Bush has been interested in the design of advanced mathematical analyzing instruments and has had charge of a group of research workers who have produced several important instruments of this type. In recognition of this work he was awarded the Levy Medal of the Franklin Institute in 1928 and the Lamme Medal of the American Institute of Mining Engineers in 1926.

As president of the Carnegie Institution, Dr. Bush will hold an administrative position in one of the largest foundations devoted to the advancement of knowledge by research. Its resources include various research stations and its interests range from astronomy to archeology. Among the branches of the institution are the Mount Wilson Observatory, in California; the Desert Laboratory, at Tucson, Arizona; the Station for Experimental Evolution, at Cold Spring

DR. VANNEVAR BUSH

VICE-PRESIDENT AND DEAN OF ENGINEERING OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, WHO HAS BEEN ELECTED PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

Harbor, Long Island; the Biological Station in the Dry Tortugas Islands in the Gulf of Mexico; the Botanical Laboratory at Monterey, California; the Nutrition Laboratory in Boston and the Laboratory of Embryology in Baltimore. In Washington it maintains a large geophysical laboratory, a Department of Terrestrial Magnetism and a division for historical studies. The laboratories and administrative buildings in Washington are the headquarters for its scientific projects. In Mexico and Central America the institution has made extensive archeological studies of the great Mayan ruins. Its work is carried on under an endowment of approximately $34,000,000.

Commenting on the appointment of Dean Bush, Dr. Karl T. Compton, president of the institute, said:

> Dean Bush is so eminently qualified for his new position, and the post is of such great influence and opportunity in the field of science and human welfare, that his colleagues at Technology are unanimous in their approval of his selection. As they feel pride in his recognition and satisfaction in his enlarged new opportunities, they nevertheless will sadly miss his keen and ever constructive counsel and direction. To me, personally, Dean Bush has been so loyal as a friend and has shown such good judgment and analytical power in his administrative work as vice-president of the institute that it is only the magnitude of his opportunity that enables me to say that I am sincerely glad in the new situation, both for him and for the Carnegie Institution. His rare capacity for making an original constructive contribution to the solution of every problem that comes to him will be a great asset in directing the far-flung affairs of the Carnegie Institution.

SEISMIC WAVES

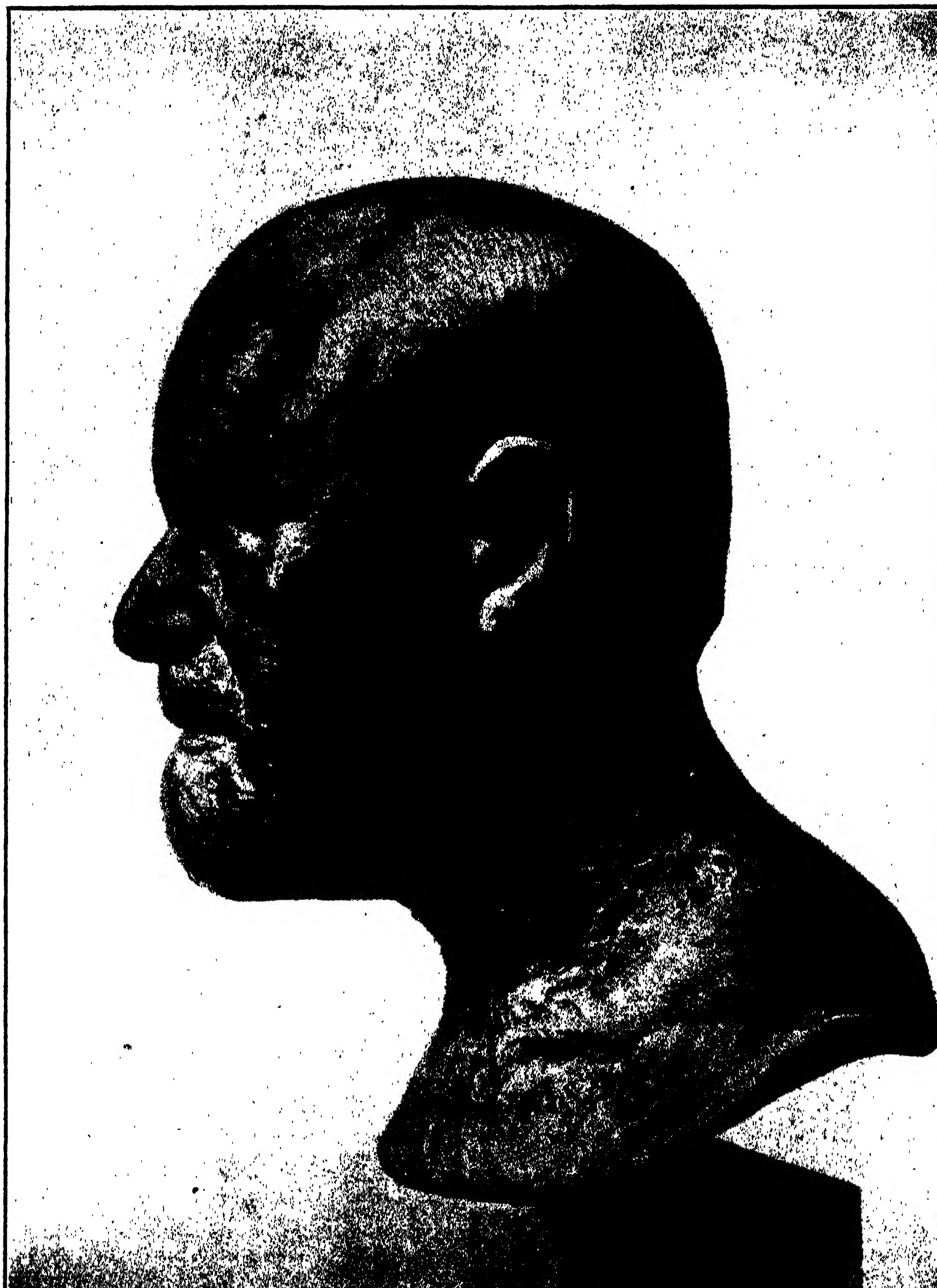
The Geological Society of America announces that artificial earthquakes, set off by powerful quarry blasts, will be studied by geologists this summer to determine the structure of the earth's crust to depths more than twenty miles below the surface. Observing staffs will be stationed at varying distances from several large quarries in New England with instruments more delicate and more sensitive than those usually employed in measuring real earthquakes.

Dr. Louis B. Slichter, professor of geophysics at the Massachusetts Institute of Technology, will direct the study under a grant of $5,350 from the Penrose bequest of the society. Dr. Slichter hopes that the recording of the blasts will shed light on the popular geological hypothesis that the earth's crust is composed of a number of layers of rock, not unlike the physical make-up of the onion.

Fresh knowledge concerning the structure of the earth's crust at depths of twenty miles and more, and new data on the nature and depth of the transition from the layer of granite to the underlying rocks, is one object of the investigation. At present the earth is conceived by some geologists to consist of a series of concentric shells; an outer layer of sedimentary rocks, an underlying granite-gneiss shell, a shell of periodotite or basic rock and a core of nickel and iron, with a transitional layer between the periodotite and the core. To bolster or deflate this theory is another objective.

Twelve super-sensitive portable seismographs, especially designed by Dr. Slichter for the project, will be placed at regular intervals within a hundred miles or more from the point of the blast to record the results of the man-made earthquakes. Supplemented by radio receiving apparatus and a central control board, each seismograph station will be equipped to record most microscopic tremors. More than twenty-four observers will man the field stations.

The gigantic blast will be recorded on instruments many miles away as a series of jagged lines. So delicate are the



DR. SIGMUND FREUD

FOUNDER OF PSYCHOANALYSIS, WHO HAS BEEN DRIVEN FROM VIENNA AT THE AGE OF EIGHTY-TWO YEARS AND IS NOW LIVING IN LONDON. THE BUST, BY PAUL KÖNIGSBERGER, WAS MADE ON DR. FREUD'S SEVENTY-FIFTH BIRTHDAY FOR THE GERMAN PSYCHOANALYTIC SOCIETY.

SUPERSENSITIVE SEISMOGRAPH TO RECORD MAN-MADE EARTHQUAKES

DR. LOUIS B. SLICHTER ADJUSTING ONE OF THE TWELVE NEW SUPERSENSITIVE SEISMOGRAPHS WHICH, IN A STUDY SPONSORED BY THE GEOLOGICAL SOCIETY OF AMERICA, WILL BE USED THIS SUMMER TO RECORD ARTIFICIAL EARTHQUAKES SET OFF BY QUARRY BLASTS IN NEW ENGLAND. EARTH MOVEMENTS AS SLIGHT AS A HUNDRED THOUSANDTH OF AN INCH CAN BE RECORDED WITH THE DEVICE, WHICH IS MORE DELICATE AND MORE SENSITIVE THAN THE ORDINARY SEISMOGRAPH WHICH RECORDS REAL EARTHQUAKES.

supersensitive seismographs that they are capable of detecting a ground movement as slight as a hundred-thousandth of an inch. The size of the blast will determine the distances at which the field stations will be located.

It is expected to obtain information on the nature of rocks at varying depths by measuring the time elapsing between the detonation and the recording of the shock at the field stations. Through a microphone and radio transmitting apparatus at the scene of the blast, all field stations are simultaneously apprised of the explosion, which is automatically recorded on a tape.

When the ground tremors finally reach the machine through different underground paths, they are registered on the same tape. The space on the tape between the record of the blast as received by radio and the record marked by the seismograph gives the time consumed by the tremors in reaching the field stations. These records will be analyzed and calculated by special machines at the Massachusetts Institute of Technology.

Seismic waves travel more swiftly in rocks of increasing depth. Dr. Slichter expects that his research will determine accurately how swift wave velocities travel in the deeper crustal rocks. The part played by depth in the variation of wave velocities will also be investigated.

While the actual field work will be completed this summer, the entire program, including interpretation of the results in the laboratories of the Massachusetts Institute of Technology, will occupy a year.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1938

CLIMATIC CYCLES AND HUMAN POPULATIONS IN THE GREAT PLAINS[1]

By Dr. FREDERIC E. CLEMENTS

THE CARNEGIE INSTITUTION OF WASHINGTON

I

EVERY one is doubtless familiar with the account of a climatic cycle and its effects which appears in the Book of Genesis. The seven fat and the seven lean years suggest that this coincided with the well-known sun-spot cycle, which usually ranges between 10 and 14 years. The seasons of rainfall and drought, of plenty and famine, bear a close resemblance to recent periods of abundance and want. Accordingly, Joseph must receive the credit for issuing the first known long-range forecasts of rainfall and drought. He also achieved a world's record for verification, which has not even yet been equalled in these modern times. Moreover, he was not only the first to propose but also the first to operate successfully an ever-normal granary. Another cycle —or rather, another expression of the same one—was mentioned by Bacon at the beginning of the seventeenth century, when he said that every 5 and 30 years in the Low Countries the same kind of weather is reported to come about again, such as great wet, great droughts, great frosts and warm winters, and that in computing backward he found some concurrence.

More than two centuries later, the Swiss geographer, Brückner, rediscovered this 35-year cycle, which came to be known by his name. Brückner used all the long records of rainfall and temperature then available and was able to extend his study as far back as 1020 A. D. by employing known changes in

Carnegie Institution of Washington

FIG. 1. THE ELEVEN-YEAR SUNSPOT CYCLE IN THE ANNUAL RINGS OF A SCOTCH PINE TREE (AFTER DOUGLASS).

[1] Presented in a symposium on the "Scientific Aspects of the Control of Drifting Soils," Denver meeting of the American Association for the Advancement of Science.

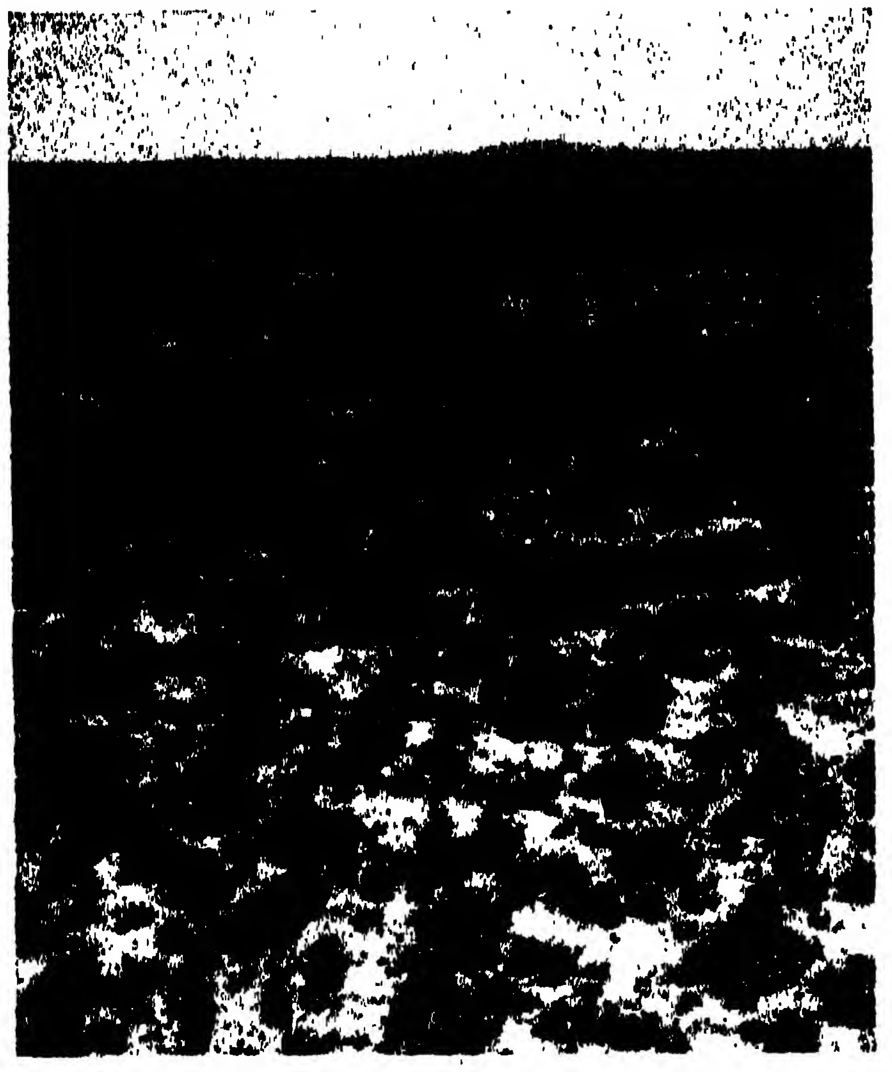
level of the Caspian and other seas, the records of ice conditions and severe winters, and the dates of poor wine-grape harvests. He recognized 25 cycles between 1020 and 1890; though their average length was 35 years they varied from 20 to 50 years, which suggests that they, too, perhaps were multiples of the sunspot cycle. More recently, Douglass and Huntington have found similar cycles in the annual rings of trees, and the former has made brilliant use of them in dating prehistoric pueblos of the Southwest. He likewise has discovered evidence of dry and wet periods in the rings of fossil trees that flourished millions of years ago. Moreover, seasonal melting of the ice as the continental glaciers withdrew to the north at the close of the Glacial Period produced characteristic annual layers in which Antevs has found cycles, and some 40,000,000 years ago similar deposits were being laid down in the Green River lakes of northeastern Utah and southwestern Wyoming.

Those who have traveled to the Rockies from the East have crossed the short-grass country and have seen the low sod of grasses to which it owes its name. Since the days of trapper and pioneer, these have been known as buffalo grasses, not so much because bison preferred them as because the animals grazed off the taller grasses and left the shorter ones in their wake during spring and fall migrations. When cattle succeeded the bison and were held in herds or under fence, they grazed much more closely than the moving bison, keeping the plant cover in the short-grass condition almost constantly. This effect was naturally greatest in dry or drought years, so that the buffalo grasses logically appeared to be indicators of arid climate. The first suggestion of this relation was made by two young botanists, just on the threshold of ecology, who explored the sandhills of Nebraska in 1892 and 1893, on the eve of a more devastating drought than the West had known before that time.

Almost everywhere, these botanists

Soil Conservation Service

FIG. 2. SHORT-GRASS COVER OF BLUE GRAMA AND OTHER GRASSES IN THE TEXAS PANHANDLE.



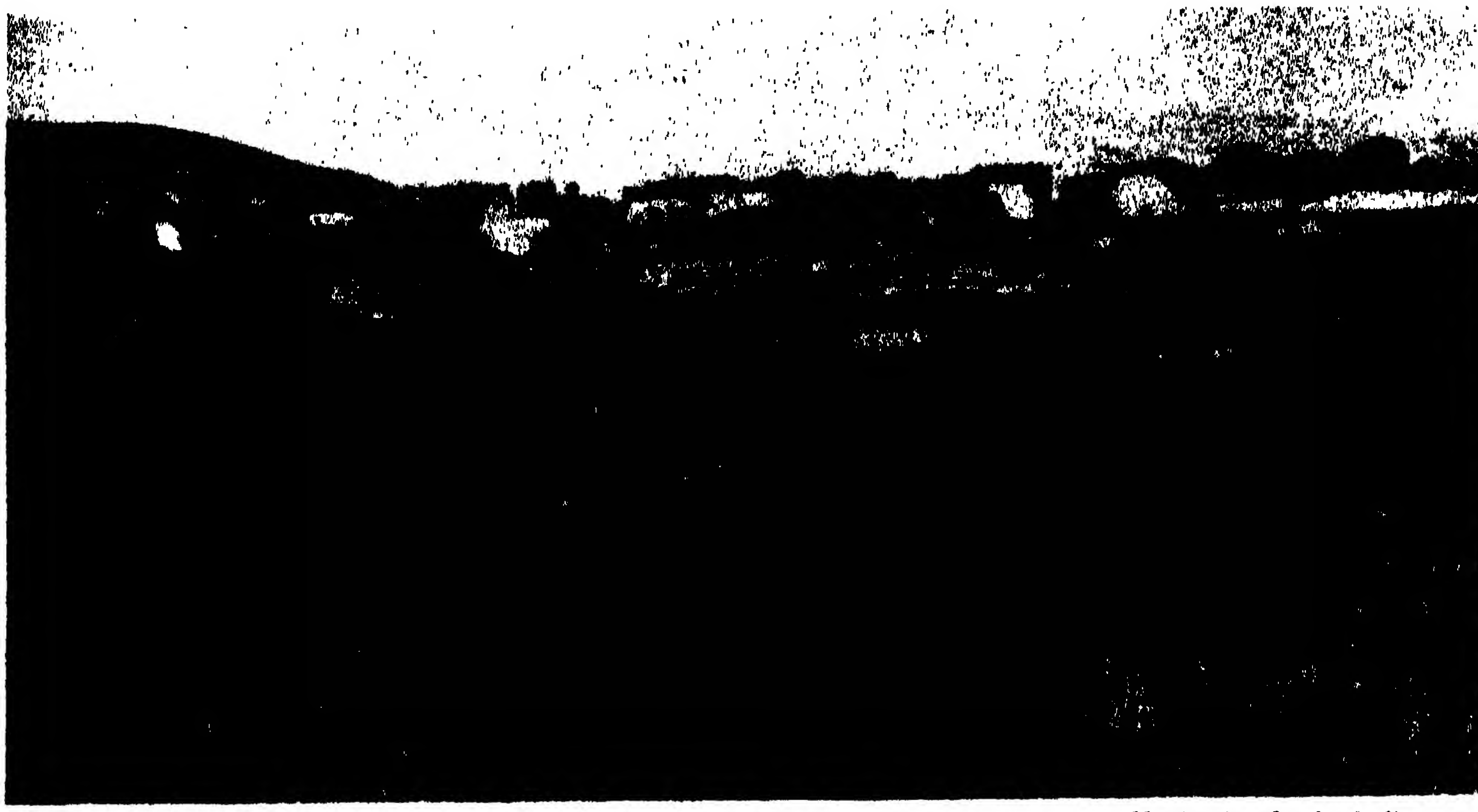
U. S. Geological Survey

FIG. 3. SHORT-GRASS COVER OF BLUE GRAMA, BUFFALO GRASS AND OTHER GRASSES; SERIOUSLY AFFECTED BY OVERGRAZING AND DROUGHT. "DUST BOWL," 1937.

found a close curly sod of buffalo and grama grasses, and they naturally concluded that this represented the normal forage crop of that particular climate—as it did for the time being. The tall grasses had not only suffered most from drought itself; they also had been grazed so closely that they either seemed to be absent or at least to be unimportant. As a consequence, the opinion arose that short-grass indicated a climate too dry for farming and adapted only to the cattle industry. This view became current among biologists and there was little occasion to doubt its accuracy before the exceptionally wet summers of 1914–15, when tall grasses seemed to spring up by magic. Relicts of the original grassland have since been discovered in all sorts of protected locations, the most interesting and best dated being the cemeteries of frontier towns, while the most wide-spread and extensive are the fenced right-of-ways of railroads.

Exploration during the two decades has proved that taller and shorter grasses live together where the former have not been destroyed by grazing. To make the proof conclusive, small areas of a few acres each were fenced off as early as 20 years ago in various parts of the West, in cooperation with the Forest Service, Biological Survey and state experiment stations. The desired evidence promptly appeared in the form of mixed prairie, so called because a layer of tall-grass developed above the short-grass sod and reduced both grama and buffalo grasses to a secondary rôle. The narratives of early explorers and forty-niners furnish further proof that the original plains vegetation was mixed. However, the most decisive testimony has come from photographs taken by the Hayden geological expeditions in the Great Plains between 1867 and 1870. These pictures depict an undisturbed landscape with a luxuriant cover of tall wheat, spear and blue grasses, beneath which their shorter companions are completely hidden. The omnipresent sagebrush of later days, which has spread widely because of overgrazing and recurrent drought, is nowhere to be seen.

However, in scientific matters as with the daily press, correction is often slow to overtake the original fallacy. On the ground, short-grass seems convincing. Any one who sees it can understand why the view that it is a trustworthy indicator of climate and crops still persists in some quarters. Recent recommendations for the removal of a large part of our western population have been based upon the assumption that short-grass is the natural vegetation of the Great Plains, that this proves the region to be unfitted for crops and that a great reduction in population therefore is imperative. On the contrary, we know beyond question that short-grass is a man-made cover, and we are confident that rain and drought will continue to follow each other as they have done in past cen-



U. S. Geological Survey

FIG. 4. CLIMAX PRAIRIE OF MID- AND SHORT-GRASSES IN EASTERN WYOMING, 1870. PHOTOGRAPH BY W. H. JACKSON, OF THE HAYDEN SURVEY.

turies. If they do, average crop yields for the next 10 years will equal or exceed those of the present decade, with its heavy burden of drought.

II

The first homestead act, of 1862, stimulated thousands of men released from military service to test their fortunes in the fertile prairie soils of eastern Nebraska and Kansas. A few years later they met the first turn of the cycle in the disillusioning drought period of the early seventies, and this misfortune was rendered all the more tragic by the most devastating plague of grasshoppers known in America. These adverse conditions partly checked the wave of migration, but a favorable shift of the cycle for the next 10 years inspired the greatest inrush of settlers known in the peopling of the West. With memories of grasshopper years in mind, pioneer and newcomer alike felt that drought and hard times had passed for good and that the future held nothing but timely rains and bountiful crops. This feeling was capitalized by those with lands to sell or commonwealths to build, and in good faith even men of science gave their support to the myth that the climate had permanently changed for the better as a result of settlement and cultivation. Such beliefs were disturbed by the drought of 1889 and shattered for a generation by that of 1893–95, when the exodus from the parched regions sent a half million settlers across the Missouri River and back to their homes in the East.

The passing of the drought years found a new generation of home-seekers pressing into the Great Plains after two periods of remarkable rainfall, the first lasting from 1905 to 1909 and the second from 1914 to 1916. This later migration was intensified by the war-time demand for wheat, and the severe drought of 1917–19 went almost unheeded amid fabulous prices for grain. A dry year now and then passed with scant notice until the collapse of the world market for wheat produced chronic agricultural depression, which became acute with the crash of 1929 and the onset of general drought a year or two later. To-day, many persons believe that the last seven lean years have been a period of all but

complete failure of both rain and crops. We shall see that this picture is not generally true, even for the most arid districts. Drought is now front-page news, a local dust-storm wears seven-league boots and a true sense of proportion can be secured only by wide perspective extending through decades.

III

We customarily think that the rainfall of a special year shows a fairly uniform pattern of amount and distribution in any selected region. It actually may vary widely, much as it does in a single storm. Almost every one, in these times of fast motor-cars, has had the experience of driving out of one storm and into another. One also may drive from areas where rains have been plentiful to near-by places, where they have been scanty. Close uniformity in terms of well-known regional tendencies is reached only during the driest or wettest years, and even these may show striking local variations. Nevertheless, precipitation is not normally a hit-or-miss affair, for the very nature of forest, prairie and desert demonstrates that rainfall patterns are distinct. No two neighboring localities in the same region can maintain a material difference over a number of years without differing in their characteristic or climax vegetation.

In seeking to explain the alternation of dry and rainy phases within cycles and the chain of consequences that lead to shifting populations, we may logically turn to fluctuations of the sun as the earth's source of energy. Such at-

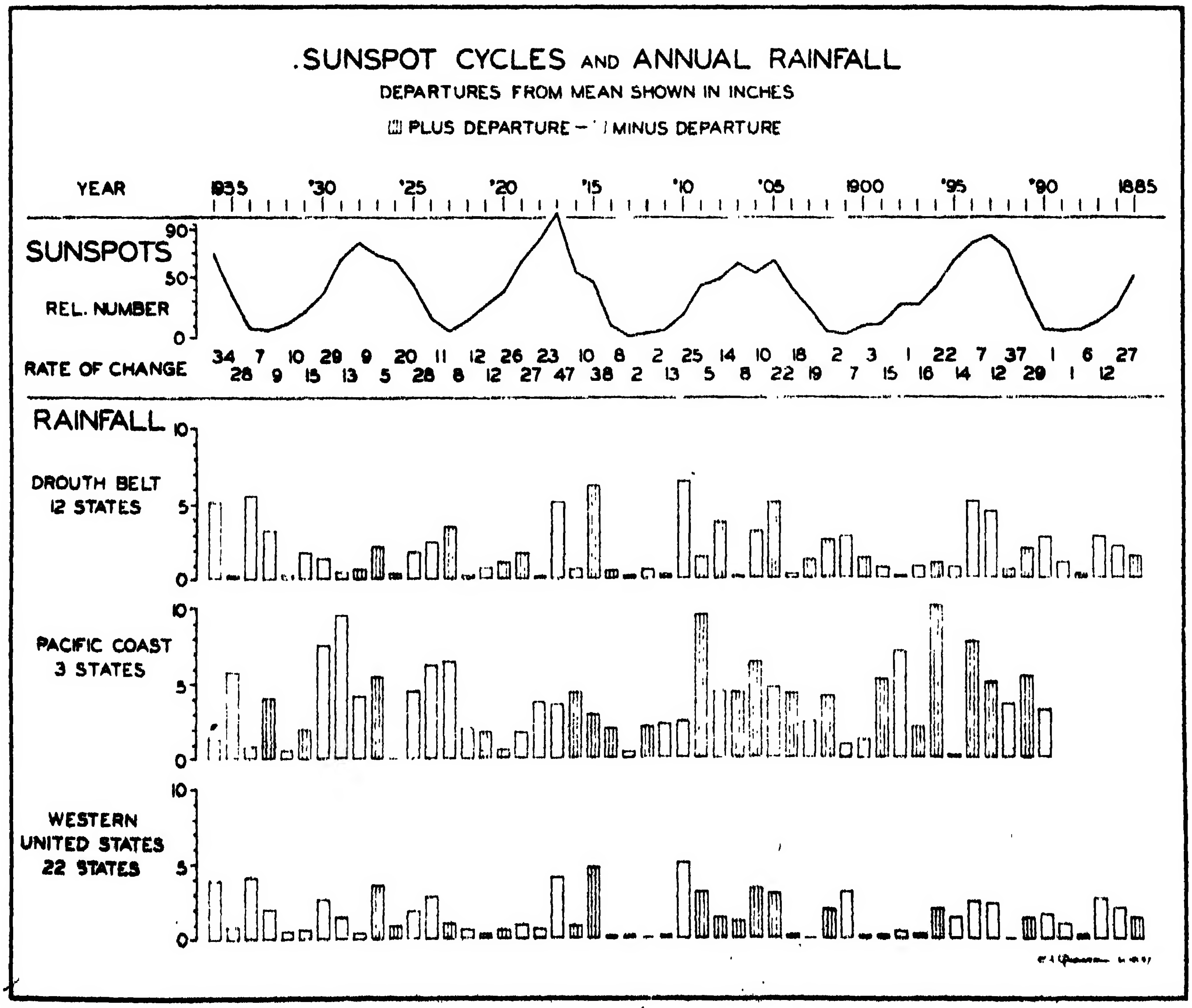


FIG. 5. SUNSPOT CYCLES AND ANNUAL RAINFALL IN THE WESTERN UNITED STATES IN RELATION TO SUNSPOT MAXIMA AND MINIMA AND RATE OF CHANGE IN NUMBERS FROM YEAR TO YEAR.

tempts have been made with increasing frequency during the past 70 years. Most of these inquiries have found some agreement between dry or wet periods and the variations in solar radiation which are indicated by the number of sun-spots; in some studies, at least, the correspondence is striking. In the hope of discovering a connection between drought and sunspot extremes, the rainfall records of all stations in the Middle and Far West were compiled in 1921. The first result of this study was the discovery that the three greatest droughts coincided with the greatest sun-spot maxima (of 1870–72, 1893–95 and 1917–19), when the number of sunspots for each of the three maximal years averaged 85 or more. The alternate maxima of 1883 and 1905 were marked by a relatively low number of 63 spots, and rains were generally good to excellent in and about these years. Tentative forecasts of a maximum of about 100 spots in 1917, attended by serious drought, and of approximately 75 spots in 1928, with normal rainfall, were verified.

Through the cooperation of the Works Progress Administration and the Forest Service, rainfall records are now being compiled in terms of excess and deficit (contrasted with the mean amount) for the whole North American continent. The first fruit of this project is a table of state averages and their annual departures from the mean, beginning with 1876. This table confirms the occurrence of droughts at high sunspot maxima and it also reveals a marked tendency to drought years at times when spots are fewest. Furthermore, it not only corroborates the trend toward normal precipitation at the low maxima of 1883, 1905 and 1928, but also discloses that normal rainfall or better occurs between sun-spot extremes. Fig. 5, based upon this table, does not include the drought of 1870, but it shows that two great droughts fell at the high maxima of 1893 and 1917, while similar deficiencies occurred at the five minima between 1890 and 1933. However, this leaves unexplained the dry years of 1886–87, 1910, 1925 and 1930–31. Their cause is suggested by the fact that each coincides with an abrupt change of 25 to 30 sunspots in the direction of either maximum or minimum.

The periods of good rains in the last half century have been 1875–78, 1881–85, 1902–09, 1914–15, 1920–23 and 1926–28, with frequent single years intervening. Beginning with 1929, the departure from normal in the West generally and in the drought-belt in particular has been uniformly minus, although the deficit was slight in 1929, 1932 and 1935. The dry period of 1929–36 is the most nearly continuous that has been recorded for the United States, but the interval of 1893–1901 was virtually as severe. Bad as it has been, the severity of the recent drought has been much overestimated, largely because of dramatic dust-storms. This reassuring opinion will be supported by a consideration of the potential crop-yields for the past decade.

IV

In a state of nature, probably no living thing escapes the ravages of drought in some form or degree. The effects are felt first by plants and especially by annuals, whose fate depends upon a single season. The great crops of the western world—corn, wheat and other small grains, cotton and sorghums—are annuals, most of which are subject to the whims of a hot summer, when a few days may do irreparable damage. Nature's crops, with the exception of weeds, are largely perennial; this is specially true of the plants that make up the great vegetations or climaxes. It is practically impossible for a drought of several years to do more than stunt them, unless man has complicated the situation. Most insects, as well as many other animals, live as adults during a single season, and resemble annual plants in being highly

responsive to drought. Those of longer life-span, such as birds and mammals, respond more slowly and their numbers fluctuate to correspond, rising or falling during cycles of several years. In the case of grasshoppers or locusts and certain rodents, periodic increase is often so great that it produces veritable plagues, like those which marked the grasshopper years of the seventies. Grasshopper plagues in the West seem to be direct results of migration caused by drought; this relationship apparently has existed in Europe and the Orient since Biblical days. Between the time of Charlemagne and 1862, the migratory locust invaded Europe 132 times, and 22 of those invasions were devastating plagues of the first order.

In the Far North, the periodic shifts in the populations of snow-shoe rabbits or hares are of tragic importance to Indian tribes and to such predators as the lynx, fox and marten, whose basic food is rabbit meat. These variations are the best documented of all animal cycles, since an exact record of the fur trade has been kept by the Hudson Bay Company for more than 100 years. Seton has shown graphically the fluctuations in rabbit numbers and the corresponding rise and fall in the number of the snow-shoe's chief enemies. These variations corresponded closely. There also is general agreement between times of maximal numbers and sun-spot minima, probably because there is greater warmth and better plant growth at such periods.

The last act in the full cycle of climate is the movement of human populations. This, in itself, is a cycle of advance and retreat. There have been four chief occasions for such tide-like movements in the West, in which the advance was timed by superior rainfall and good crops, while backward movement matched drought and crop failure. The first two crises fell in the early seventies and nineties, at times of high sun-spot maxima; the third came at the maximum of 1917 during war-time, with its high markets and greatly reduced man-power, and it consequently received little notice. The fourth and last occurred in the midst of depression, when the machinery of relief already was in action, so that the usual mass movement eastward did not materialize. That the question of enforced depopulation is a critical one is shown by the attitude of the Great Plains Committee. In August, 1936, it expressed the opinion that the region could sustain its existing population; a few months later, it wondered whether reduction in numbers might be imperative. Its final conclusion, which appeared early in 1937, will receive consideration later.

Meanwhile, a nation-wide study of economic conditions, entitled "Migration and Economic Opportunity," has been published, the view set forth in this report being: "In the case of the Great Plains, the minimum exodus 'consistent with safe use of the land' would be a quarter of a million people and the ideal economy would require the removal of nearly three times as many. . . . It is our judgment that the long-run direction of movement must be toward the urban areas and hence there cannot fail to be large movements from agriculture into other occupations." The report goes on to consider what these occupations are and the possibilities of jobs in them. After canvassing the national situation, it rather obviously indicates that there is only one other occupation for the 750,000 people to be moved out of the Great Plains, and that is work-relief.

V

Dust-storms, soil-drift and floods during the past five years have made such a convincing case against man's handling of the soil that the verdict is unanimous and the task is now to carry it promptly and fully into effect. As Dr. Bennett has shown, this is being done with increasing success throughout the Great

Plains by the Soil Conservation Service, and the task of the ecologist as a student of environment is chiefly to analyze the rôle of vegetation in the processes of protection and recovery, in order to obtain a properly balanced control for the future.

There is nothing mysterious about the way in which plants act to hold particles of soil in place, but the combinations of different plant covers, soils, climatic conditions and human disturbances are innumerable. As a result, a matter which is simple in its essentials may become complex in practice. Moreover, vegetation not only protects the soil upon which it grows, but it also exerts a beneficial action for considerable distances beyond. This is easily seen in the case of windbreaks and shelterbelts; and it applies equally though less conspicuously to crops grown in strips, and even to individual clumps of grasses. In all cases, plants slacken the movement of wind or water and reduce or even destroy their power to move loose particles of soil.

This ability to protect soil varies much with the kind of plant and the form of its stem and roots. Tall stems and dense tops make trees the first choice for windbreaks; shrubs and bushes rank next, while grasses and herbs come last. However, when we turn to the control of soil beneath them, grasses move up to parity with trees. The native mantle of grasses, tall or short, forms an all but perfect control of erosion by wind or water and continues to hold the soil against the force of the wind until nine tenths or more of the surface is exposed by overgrazing.

Dead grasses may protect the soil almost as well as living ones, and they perform great service during dry periods before and after the growing season. Stubble gives comparable protection to grain-fields after harvest and permits methods of control in which seed is drilled into the ground without plowing. Stubble also may be saved as a litter which prevents blowing—but not in fields which are summer-fallowed. Since drilling reduces crop-yields greatly, strip-cropping probably is the best compromise between high yields and destructive drifting of soil.

Grasses and grains (which belong to the grass family) have one further advantage. Their greatly branched roots hold the upper layer of soil so firmly that particles often can be removed only with a power-stream. Since comparable agents are rare in nature, these roots give unusually strong protection against soil removal by either flowing water or wind.

Grasses of the Great Plains take two familiar forms, known as *sod* and *bunch*. Bunch grasses are the more numerous, for their habits fit the prevailing dry climate. They usually are much taller than the sod grasses and have larger, denser root systems, but they cover the ground less uniformly than do the sod-formers. This latter group includes such outstanding types as wheat grass, buffalo grass and one or two of the grama grasses—if they grow under favorable conditions. Their stems are spaced closely and uniformly; all but wheat grass are short-grasses whose leaves form a more or less dense mat. They spread readily by means of rootstocks in the soil and runners upon the surface. Thanks to this ability, they surpass other plains grasses in ability to resist overgrazing and other disturbances.

Grasses also are divided into tall, medium (or mid-) and short groups, according to their comparative heights. Stature corresponds closely to growing conditions and especially to available water. The three groups therefore reflect both the amount of moisture in the soil and the rain that falls upon it. Tall-grasses, such as bluestem and sandgrass, require much water and hence occupy valleys or sandhills; the mid-grasses generally prefer sandy loams with less available water; and such short-grasses as

grama, buffalo and wheat grass select the fine soils of the so-called hard-lands. When uncovered, the degree to which these soils will blow is determined chiefly by their texture and the amount of organic matter and water in them. Sandhills shift about constantly when they are exposed; the others drift less and less as their sand content decreases. It is an interesting correlation that sand, which blows most readily, is covered by the tallest grasses, the intermediate soils chiefly by mid-grasses and the fine, compact silts by buffalo grass. However, the protective values of these three types are much more alike than their stature seems to indicate. Under natural conditions any one of them affords an almost perfect control against the strongest winds.

To appreciate how effectively grasses and weeds protect the soil surface, we need only to notice that they form miniature windbreaks. In this rôle, they reduce the wind velocity for a distance to the leeward that may be as much as 20 times their height. This is several times the distance between bunches of tall-grass and the same relationship holds among the short-grasses, which stand much more closely. Even a very open cover of native grasses will prevent wind erosion: a fact that is readily confirmed when we measure the effects of different grasses upon high wind velocities. Wheat grass completely stills a wind of approximately 18 miles an hour at three inches above the ground-level, while short-grasses decreased it 20 to 25 times.

When vegetation catches and holds soil particles, it keeps the wind from picking them up to form soil-drift or dust-storms. Soil-drift means deposition, which builds dunes on farmlands as well as along seacoasts and river-valleys; if uncontrolled, it buries windbreaks and fences and overwhelms farm buildings. Obviously, the best method of control is to prevent wind erosion, but until this is achieved generally, deposition must be brought about where it will do the least harm. Windbreaks therefore must be planted far enough to the windward of homes so that

FIG. 6. ABANDONED FIELD IN THE SANDHILLS OF NEBRASKA. IT IS CONTROLLED BY THE NATIVE TUMBLEWEED.

silt is caught and dropped before it reaches farmyards, or an outer low windbreak may be used to catch soil before it piles about the windbreak proper. Russian thistle and other tumble-weeds are especially undesirable because they come to rest along fences and windbreaks and thus produce deep drifts. Such tumbleweeds can thrive, however, only in soil that is cultivated or otherwise disturbed. A pasture strip to the windward of buildings will almost always eliminate danger from them.

Some writers believe that dust storms have occurred commonly throughout the later geological past and that deposits hundreds and even thousands of feet thick were produced by wind action. Without presenting the ecological evidence in detail, we may say that even a thin cover of vegetation controls the wind so effectively that soil-drift and deposition during the past must have been limited to bare areas such as ocean-strands and river-banks. During the historical period, dust storms have come only from soils exposed by man in the course of settlement.

Of all the forces that act upon plant cover to destroy its protective power, those released by man are by far the most potent. The only natural one of great significance and wide extent is drought, though floods and animals may exert much local effect. Even drought is chiefly contributory and the train of events which lead to soil drift and dust storms is regularly set in motion by disturbances due to man. All these—cultivation, fire, grazing, road-building, etc.—lay the land surface bare and provide opportunity for erosion.

The control of wind or water erosion must be accomplished for the most part by means of vegetation; all other aids are merely contributory or are to be employed when the protective effect of plants is absent or while plants are being restored. Wind is more readily controlled than is water, since even an open

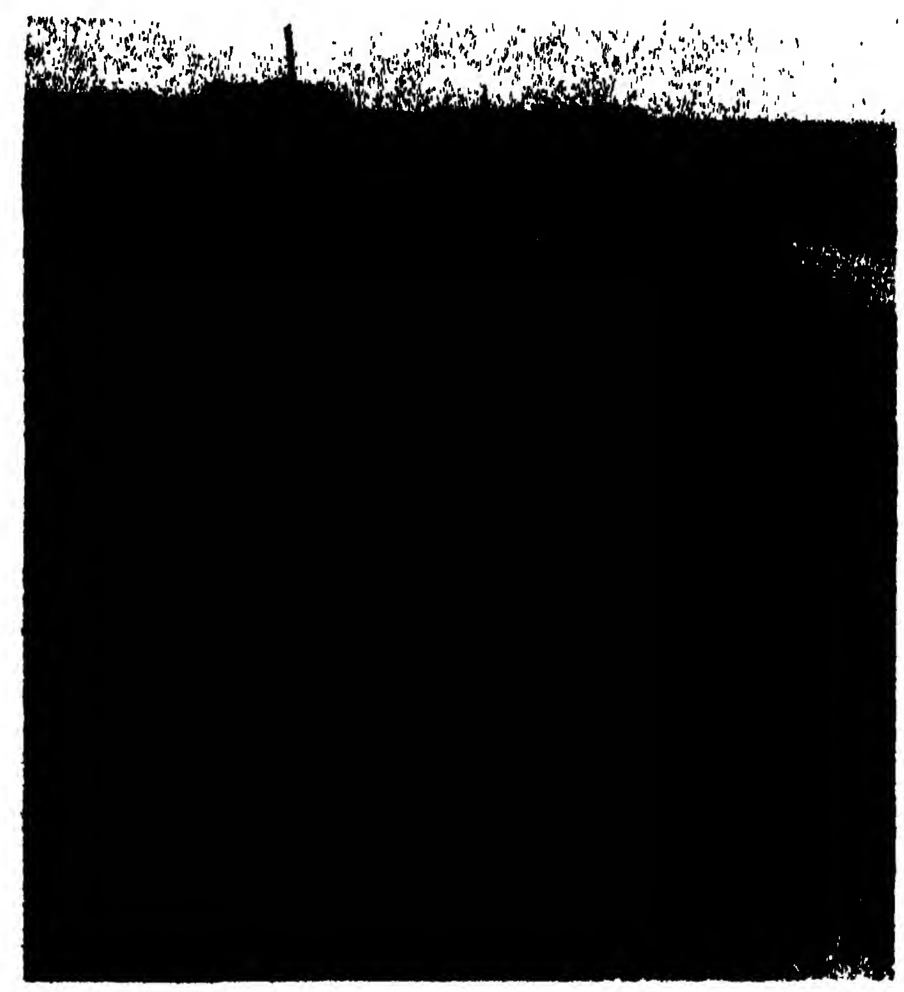


FIG. 7. FENCE BURIED BY DRIFTING SOIL WHICH IS HELD BY A COVER OF ANNUALS, RUSSIAN THISTLE AND PIGWEED.

cover does this effectively, not only beneath it but for considerable distance to the leeward. For the nearly complete control of runoff and erosion, a dense cover is necessary. Where cultivation of fields keeps such cover from growing, terraces, dikes and furrows must be used as reinforcements to plants. On the Great Plains, similar aids should be utilized where overgrazing has become a menace during drought and renewed rains will bring volumes of water that the impoverished pastures can not retain until it is absorbed.

VI

So thorough is the control exercised by native grassland that the return of croplands to grass in the Great Plains has come to be generally regarded as the proper, if not the sole, solution of the problems brought in the train of drought and abandonment of crops. This belief, however, has failed to take into account several critical considerations, namely, that drought itself, though recurrent, is always transient, that methods of proper cropping and erosion control have been developed and are being applied with increasing success, and that restoration of

grass-cover involves much more than the mere broadcasting of seed over a landscape.

For two generations, attempts have been made to rejuvenate over-grazed or wornout ranges by the simple device of sowing seed and leaving the rest to nature. Such efforts have been uniform failures, except under moisture conditions that rarely occur. As a consequence, we have been forced to look more closely into nature's ways in order to discover how she succeeds in improving pastures and re-covering abandoned fields when given the opportunity. With these facts in hand, we are able to speed up natural processes, to use other or better plants than those now available and to broaden the field of action. More than this, we can press into service some of the practices of cultivation and can secure combined forage and protection values resembling those found in fields of perennial crops. In such cases, the problem is narrowed to finding and maintaining the best grass crop and, of course,

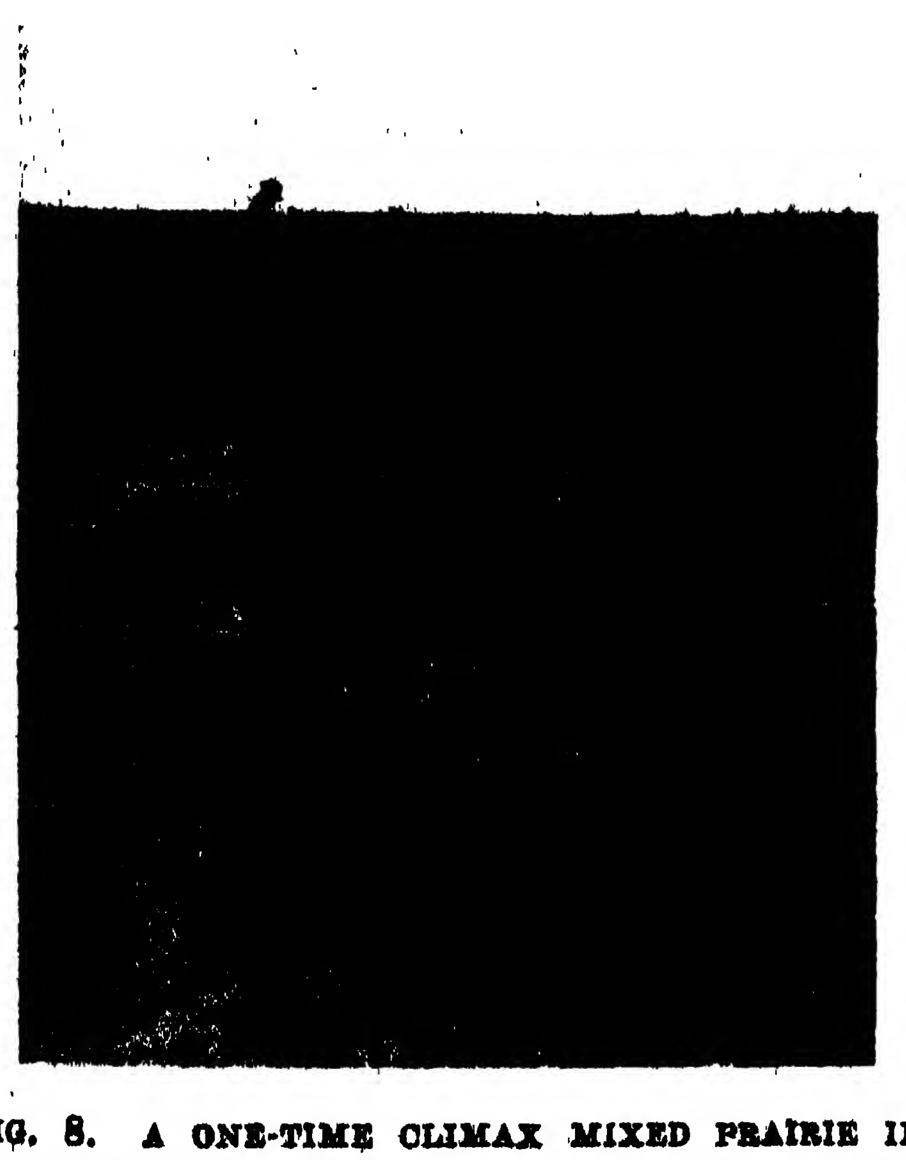


FIG. 8. A ONE-TIME CLIMAX MIXED PRAIRIE IN EASTERN COLORADO. OVERGRAZING AND DROUGHT REDUCED IT TO SHORT-GRASS; CONTINUED OVERGRAZING AND DROUGHT DESTROYED MOST OF THE SHORT-GRASS, WHICH NOW IS REPLACED BY PRICKLY PEAR.

to securing the man-power or money needed to do this work.

When does grazing become over-grazing? The best answer is that this happens when weeds begin to increase in numbers at the expense of grasses. Since two compete keenly for a limited water-supply, anything more than moderate grazing throws the balance in favor of the weeds. The grass then decreases in amount, but since it is still called upon to support the same number of cattle, it suffers further handicap in its struggle with the weeds. Each step in the destruction of the forage cover is marked by the appearance of other weeds, until these competitors become masters of the situation. The carrying, or grazing, capacity of the land may be reduced to a half or third and its protection against water erosion and flooding may be cut even more. So characteristic are weeds as indicators of the successive stages of deterioration that the forage production and protection value of a particular range may be estimated from the kinds and abundance of the weeds in it. When drought comes, the remaining grasses have less water for growth, competition is intensified and the demands of cattle are relatively increased. The result is that the grass cover loses ground at an accelerated rate until (to the unpracticed eye) its ruin seems complete. But fortunately, while grass may be eaten down to the roots, it is rarely if ever eaten out, but persists and is ready to renew growth under more favorable conditions.

The best cure for the ills of overgrazing is to be found in the natural recuperative powers of grasses and the chief task is to afford them a fair opportunity. Natural recovery is so much more automatic and economical than restoration by sowing or planting that it should always be given an adequate test before artificial methods are used. The essential requirement is a resting spell in which the grasses may make and store food for growth; this demands a reduced number of grazing ani-

mals per acre. Complete removal of cattle for a year or two is often desirable, but too frequently it is impossible, especially during drought. Instead, herds must rotate from pasture to pasture or grazing must stop during a special period. Since grasses are most susceptible to damage when they are becoming green in the spring, spring grazing generally should be deferred as much as possible. Delayed grazing demands an adequate supply of fodder, a fact that makes the general development of forage crops an indispensable feature of any successful farm system for the Great Plains.

The question of how far artificial regrassing is desirable must remain open until the method has been tried in the various climates and covers and the cost of assured results is determined. However, where erosion is active and the flood risk to large cities is great—as it is on the divide between the Platte and Arkansas rivers—the cost of restoring an effective cover is much less important than the speed with which it can be done. In all such areas sowing and planting should be used to hasten recovery as much as possible. Unfortunately, two of the best species for this purpose, buffalo and wheat grass, are not well adapted to this region, while a moderate reduction in stock for a year or two and regulated grazing thereafter probably would remove flood danger to cities along the mountain front. These measures must be reinforced by terraces, check dams and reservoirs to provide assurance against the occasional torrential rains which are popularly known as cloudbursts.

VII

Each receding wave of population on the plains has left in its wake thousands of abandoned fields whose management has reverted to nature. She has taken these areas in hand and in her own deliberate fashion has called in a succession of plant communities to re-establish the grass cover, beginning with weeds the first year. In some instances, this restoration of grass was a relatively simple matter; in others it was exceedingly difficult. Deep-seated disturbance, lack of a proper supply of seeds and recurring dry years hampered progress. Worst of all, such fields frequently were too quickly returned to grazing—often in the first weed stage or even by utilization of the abandoned crop. In consequence, large areas of the Great Plains are checkerboards of abandoned fields in all stages and degrees of recovery. They can be fashioned into a nicely graduated scale for the study of regeneration and utilization.

For hundreds of these fields in various districts, Savage, Judd and other workers have been able to determine the year of first or renewed cultivation, the number of years under cropping, and the date of abandonment, which determines the length of the period during which succession has acted to bring about natural recovery. The most significant discovery in this connection is that succession operates most rapidly in fields of the "suit-case-farmer," usually a city-dweller who leaves his desk or bench to sow a crop

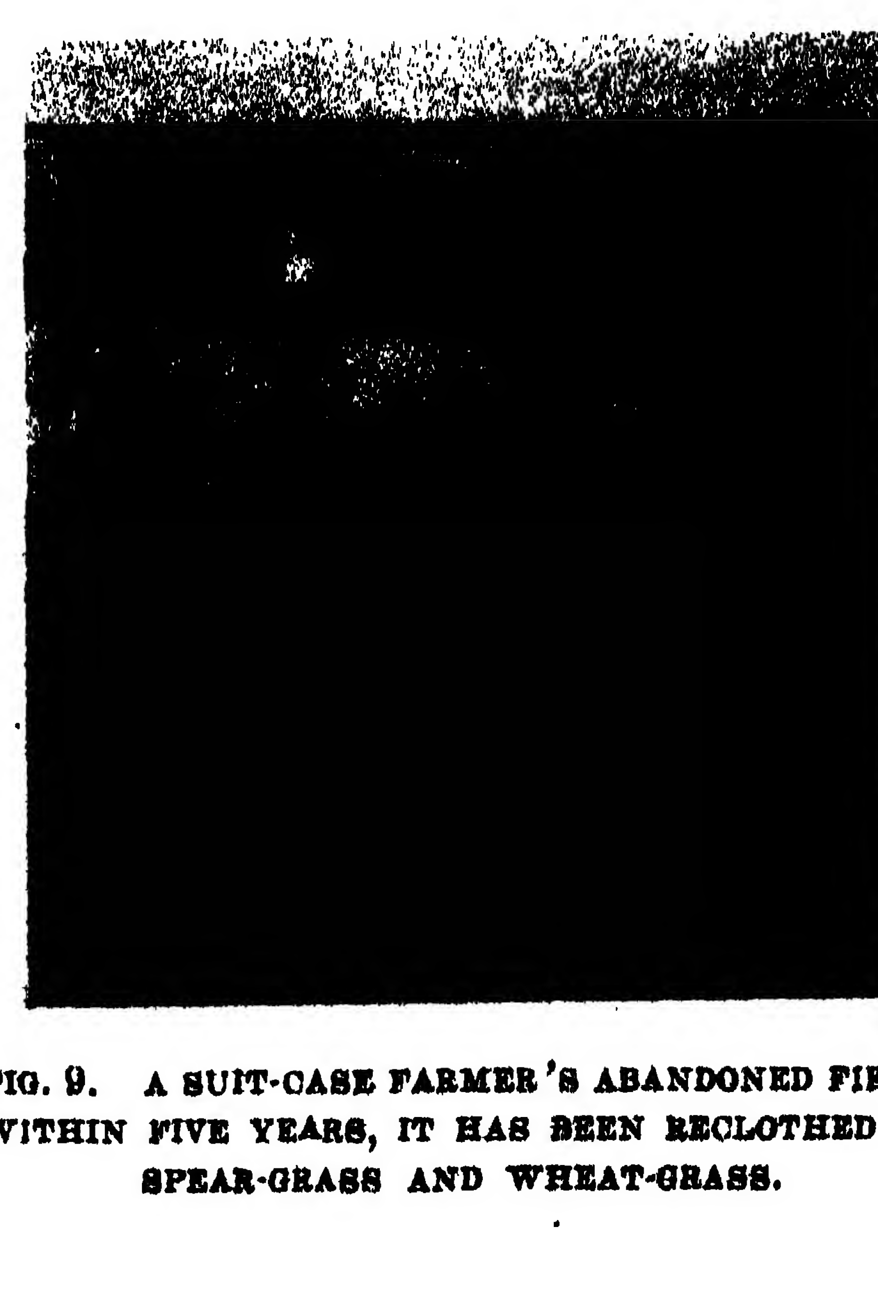


FIG. 9. A SUIT-CASE FARMER'S ABANDONED FIELD. WITHIN FIVE YEARS, IT HAS BEEN RECLOTHED BY SPEAR-GRASS AND WHEAT-GRASS.

and return later to harvest it. He embodies all the undesirable practices in cropping, plowing his field sketchily at the outset and drilling the wheat in each year without further cultivation. His methods are poor, but he does not destroy the underground perennial parts of the native grasses, which may survive as many as 16 successive crops and still be ready to reclothe the soil effectively in three to five years. Fields in sandy soils or sandhills likewise permit rapid succession and again become covered with characteristic stands of tall bunch grasses in about eight to ten years. If land values warranted it, artificial aid would doubtless hasten the process.

The situation is quite different in the finer soils of the so-called "hard lands" where cultivation has been more thorough, usually to the extent of some ploughing for each crop. Rootstocks may survive for two or three years, but in the great majority of the fields that have been abandoned four years or longer, succession depends upon seeds and hence proceeds very slowly. It is possible that some seeds remain alive in the soil for several years, but as a rule they must be blown in from adjacent areas where grazing is moderate or absent and grasses are able to produce seed. Roadsides, railways and other protected areas furnish the chief supply, especially where they lie in the direction of the prevailing wind. But under such conditions the ground is largely bare at eight to ten years and still about half exposed at 18 to 20 years, while the normal cover is usually restored only after 30 to 40 years. Obviously this is far too slow, even if grazing can be excluded, and recently abandoned fields of this type can be promptly returned to grass only by artificial methods, such as sodding with buffalo grass. Fortunately, the great majority of existing fields are now well along in the process of natural succession. Some will require no aid and others a relatively small amount, while those withdrawn from cultivation during the past five years will need complete artificial treatment, where it is deemed best not to return them to crop production.

VIII

The ecologist looks upon grassland in general and the prairies and plains in particular as almost inexhaustible reservoirs of soil fertility—of the raw mineral materials which are essential not merely to plant growth but especially to high yields. It was not by chance that grasslands of the Mississippi and Missouri valleys became the scene of the greatest corn and wheat production in the world. There were many reasons for this, but the most significant were depth of soil, abundance of available humus and minerals, presence of lime, readiness of nitrification, and number and abundance of nitrogen-fixing plants. Virtually the only limiting factor was water, whose amount was restricted by rainfall which decreased progressively to the westward, and by recurrent periods of drought. Under these conditions the advantages of wheat, especially winter wheat, soon were recognized and this grain came to be the major and too often the sole crop of the region. In spite of drought, sagging markets and justification for an expanding grazing economy, wheat continues to hold its preeminent position.

The point to be emphasized is that under proper tillage wheat has produced a fair and often a large return for a quarter of a century throughout most of the Great Plains. When it has failed more or less completely in large areas, failure has also swept across much of the subhumid Missouri Valley. In spite of its greater requirements and longer period of exposure to the vicissitudes of summer, corn also has been a profitable crop, especially when the value of forage or stover is considered. This is even truer for the grain sorghums such as milo and kafir.

The most significant fact for the solution of the population problem in the

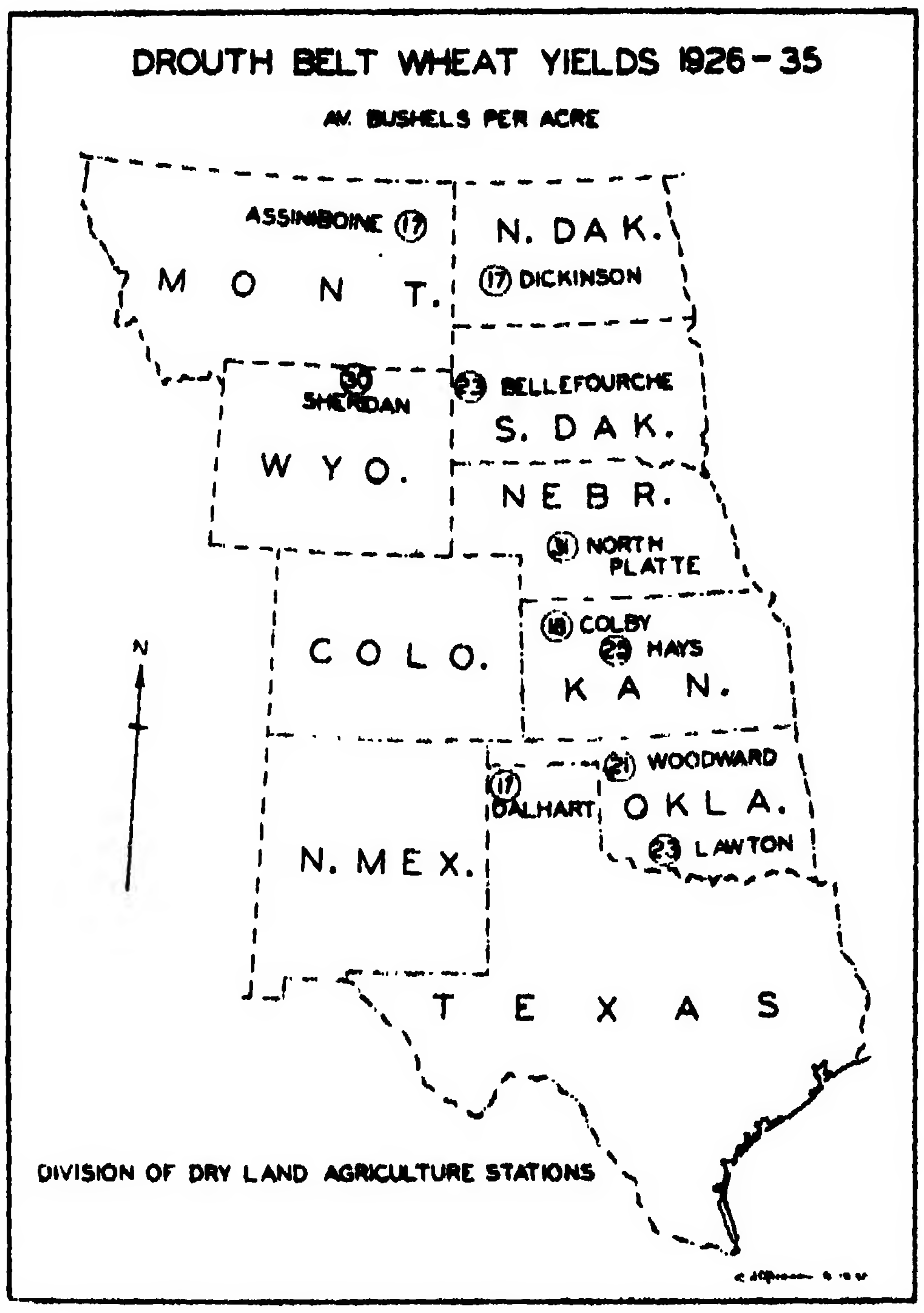


FIG. 10. AVERAGE WHEAT YIELDS IN BUSHELS PER ACRE FOR THE DECADE 1926 TO 1935, AT EXPERIMENT STATIONS OF THE DIVISION OF DRY-LAND AGRICULTURE, U. S. DEPARTMENT OF AGRICULTURE.

Great Plains is to be found in the yields of grain, and especially of wheat, at the experiment stations of the Division of Dry Land Agriculture. Along the eastern line of stations from North Dakota to Oklahoma, average wheat yields for the decade ending with 1935 ranged from 17 to 31 bushels per acre. In the western series of stations, with a rainfall several inches less but with the compensation of higher elevation, yields were practically the same: 17 to 30 bushels per acre.

With respect to balanced cropping and the feeding of stock, the average yield of corn was 20 to 22 bushels per acre, while milo ranged from 23 to 34 and kafir from 21 to 25. The fodder as a rule approximated two tons per acre.

Yields on farms in these same regions were much lower. But no one conversant with the situation expects to save agriculture and the farm population in the Great Plains by a continuance of the practices that have brought about existing conditions on average farms. The Soil Conservation Service's achievement in winning the great majority of farmers to cooperation in its demonstration projects, and in securing results far out of proportion to the brief period of its existence, shows that western agriculture can be, and is being, improved. Moreover, a direct and complete answer to the question is furnished by Charles Peacock's farms in eastern Colorado, where basin furrows are employed to retain all moisture that falls in a region whose yearly precipitation is about 16 inches. This device, coupled with a generally excellent system of tillage, has produced yields of 18 to 22 bushels of wheat per acre each year since 1932, with the exception of 1935. Failure in that year was due to grasshoppers, which took the winter wheat as fast as it appeared above ground in the fall of 1934. Since these farms enjoy no peculiar natural advantage, their crop-yields fully support the results achieved at the various dry-land stations. When the two sets of yields are combined, they leave little room for doubt as to the Great Plains' capacity for wheat production. In fact, the yields obtained during the decade of the most serious drought in our history compare most favorably with normal averages in the more humid districts several hundred miles eastward.

IX

Almost every one admits that a method of long-range forecasting as accurate as the daily predictions of the Weather Bureau would be one of the greatest conceivable boons to agriculture. The greatest achievement in this field has been the prediction of monsoon rains, by means of which the threat of famine has been reduced in India. In this country, McEwen's October predictions of winter rainfall in southern California have been so successful that his researches have re-

ceived financial assistance from utility companies interested in annual forecasts of hydro-electric power. During the 21 years of forecasting, he has obtained an agreement of 75 to 80 per cent. between predicted and recorded rainfall. For southern California, McEwen made 15, and for the Santa Barbara region 17, successful forecasts during these 21 years.

The physical system in the interior of the continent is more complex than that of the Pacific Slope and demands different methods. In the tentative effort to find a basis for prediction of rainfall in the Great Plains, solar radiation in terms of the sun-spot cycle has been the chief reliance. This has been supplemented by correlation between the rainfall of this region and that of California, where Santa Barbara is under test as a key station because of its intermediate position. This correlation has amounted to 70 per cent. since 1896 and 80 per cent. for the past 15 years. It possesses a unique advantage for prediction year by year, since California rainfall precedes that of the growing season in the Middle West by 6 or 7 months.

The first attempt to anticipate major fluctuations in rainfall on the basis of the sun-spot cycle was made in 1913 and was confirmed by a moist season. The second tentative forecast, made in 1916, anticipated the drought of 1917 from the number of sun-spots at the approaching maximum, while the third suggested fewer that 80 sun-spots for the maximum of 1928, with generally good rainfall. The drought year of 1930, which ushered in the recent dry period, was wholly unexpected, since the apparent significance of a rapid change in numbers of sun-spots had not been perceived at that time. This new index suggests a plausible explanation of drought in 1930–31, with a rate of change of 29, and in 1936 with one of 32 spots, while the sun-spot mini-

Courtesy of the Soil Conservation Service

FIG. 11. ROASTING EARS FROM THE CROP OF FIELD CORN GROWN ON THE LEVELLED DUNES IN 1937; PHOTO BY WHITFIELD.

Aerial Explorations, Inc., New York City

FIG. 12. DUST CLOUDS FROM UNTREATED LAND IN OKLAHOMA. THEY SHOW THE NEED FOR COMPLETE COOPERATION TO CONTROL SOIL-DRIFT, DUNE FORMATIONS AND DUST STORMS.

mum of 1933, which carried over into 1934, is thought to explain these dry years. The present course of the sun-spot cycle indicates a high maximum in 1938, and the forecaster is torn between the desire to see the sun-spot indexes again confirmed and the hope that good rains will temporarily contradict them.

X

Nearly 30 years ago, in connection with a classification and use survey of Minnesota, it was suggested that the farmer might well emulate the ecologist and carry a soil augur for measuring the amount of moisture in his fields. Hallstead has put this method to eminently practical account at the Hays Experiment Station; he has also shown that the farmer needs only a spade to learn the depth to which the soil is wet enough for plant growth. This depth at seeing time is closely related to the yield of wheat, a moisture layer of three feet in fairly heavy soil virtually insuring a good crop. With a shallow, wet layer, failure is frequent, and when dry weather occurs during autumn or winter, abandonment often is desirable.

The most significant outcome of the practice of testing soil moisture is that it permits an early and impersonal decision as to the advisability of abandoning the growing crop and conserving water for the next one by means of fallow, which serves to keep down weeds. In short, it gives the farmer two chances for a good wheat yield, since fallow usually produces twice as much as continuous cropping. An important item is that moisture determinations render a fairly decisive judgment at a time when the farmer is still inclined to gamble on rain. With the water-content low and rainfall deficient to April first, abandonment of the crop and the use of summer fallow is strongly indicated. To harvest the wheat crop in good years and abandon it in poor ones gives the flexibility needed in a region where dry years are not rare and drought periods are recurrent. It is a type of crop insurance that requires neither subsidy nor enormous granaries, and is peculiarly adapted to maintain the independence of the farmer while it stimulates his thinking processes.

A necessary adjunct to the combined method of anticipation and prediction is the adjustment of crops to seasonal differences in rainfall and soil moisture. In general, corn requires more water than winter wheat, wheat more than grain sorghum, which in turn uses still more than the various forage plants. The special needs and values of the different crops for the diverse regions of the Great Plains have been so thoroughly demonstrated by the various state and federal experiment stations that the information necessary is available to every farmer. The prerequisite to its general use is advance information about the farmer's capital in terms of moisture. We have found that the most important forecast can be made by the spade, but it is not improbable that this can be reinforced and anticipated year after year by means of long-range indexes.

When we turn to the related questions of population and relief in the Great Plains, two or three outstanding facts appear. The first is that in spite of a critical drought period, unequalled in duration, the population of the 10 plains states has remained virtually stationary. Obviously, this stability has been greatly helped by relief and subsidy, but these factors were not peculiar to the Great Plains. Since the population maintained itself during this most tragic of times, there is little prospect, and no necessity, of transplanting it during better years. In a sense, the farmers and ranchers of the Great Plains are still pioneers, with characteristic hardihood and attachment to wide horizons and the accompanying defects of mobility and slight feeling for cooperation. But they live on an economic and cultural level far above that

of the hill-billy and share-cropper, and by comparison constitute a simple problem. All the facts agree in demanding that their problem be solved in their own familiar environment.

The ecologist long familiar with the Great Plains entertains no doubt that this can and will be done. From the very outset, he hoped that the winds which had fashioned the drifting fields into dunes 30 feet high and a half mile long could be tamed and forced to blow them down again. This has now been done in the area once thought to be ruined beyond redemption, and crops of corn and sorghum were grown upon the flattened ridges during the summer of 1937 (Whitfield, 1938).

The most serious defect in the past has not been that of climate, natural vegetation or potential crop production. It has been the common failure to realize that the price of continued use is conservation and that conservation can be secured only by means of the most thorough cooperation. First of all this must embrace all the official agencies, federal, state and county, in any way concerned with the problem; this unification has already been accomplished to a considerable degree. It has shown farmers the necessity of cooperation among themselves, and it is upon this new development that the conservation of tomorrow should build an enduring system of use without abuse.

These ecological considerations were brought to the attention of the Great Plains Committee shortly after its pessimistic statement of October, 1936, with the consequence that its final recommendations to the President were summarized in these words:

"In this task of realizing the true and lasting values of the Great Plains, the whole nation has more than a sentimental stake. The Great Plains can be made a dependable source of a large portion of our essential food supply. Investments in their development can be secured from uncertainty, and under proper conditions new investments can be made securely. The Plains can be transformed from a risky adventure and a recurrent liability into a stable basis of economic and social profit to their inhabitants and the whole country."

THE CLASSIFICATION OF INVENTIVE IDEAS

By WM. I. WYMAN

U. S. PATENT OFFICE

BEFORE the boom broke, almost 100,000 applications for patent were filed annually in the U. S. Patent Office. The direction in interest of the coming generation is emphatically towards things mechanical. Large numbers of our population are invention-minded—if not in practical effort, at least in dreams visioning some contrivance of revolutionary effect which would incidentally leave them famous and wealthy.

Assume that our inventor has conceived something that he thinks will urge the public to beat a path to his door. Before filing an application for patent he determines to make a personal survey in the Patent Office files of the things already patented. He finds copies of over 2,000,000 American patents arranged in so-called classes and subclasses. Searching through them in the limited group in which he is interested they appear to him, uninitiated, like the sands of the sea in their overwhelmingly bewildering array. Our novice may have contrived some sort of automatic control to be used in a harvester machine, but of such general application that he is directed to search in the sub-class defined partially as "mechanisms for releasing or tripping portions of machines to cause other portions to automatically operate." He is also officially directed to search cognate subclasses in "Harvesters," "Metal Tools and Implements," "Printing," "Railways," "Motors, Expansible Chamber Type," "Brakes," "Electricity, Circuit Makers and Breakers" among a few others, where similar mechanisms may operate in conjunction with various mechanical features identified with such devices. Before he is through with his quest he becomes conscious for the first time of a different order, of a mechanical existence in diversity of association and in variety of direction beyond his conception. But why should there be any intricacy about it? Surely, steam-engines, hair-pins, radios and carburetors, to name a few items at random, are distinctly different things and no trouble should occur in placing them in different categories. And yet the government has spent hundreds of thousands of dollars to found a scheme that would group like things in classes available for the purpose for which the Patent Office was organized.

To bring like things together to form distinct groups and to separate groups according to their distinguishing properties are measures that consciously or unconsciously have been adopted by humanity from time immemorial. This cerebral process is a method of classification and is not only the basis of any scientific system but is an active principle in all systematic procedure. All ordered thought is based upon it. All ordered performances require it. Dictionaries, directories, correspondence files and trade catalogues are instances of modern requirements in domestic and business life.

The ancients had a good grasp of "logical" classification. They recognized that a class of things may be called a genus if made up of two or more species, that the latter must not overlap and that the division must be founded upon one basis. As an example, it is absurd, as all authorities on logic realize, to divide books into cloth and leather binding, French, German and history. Here are three distinct standards of identification, which overlap and through

lack of a single basis of distinction defeat the very purpose of true classification. If a purchaser expressed a choice between a French book and one bound in leather, the irrelevancy would at once be apparent.

The "state of the art" is the record of nearly all human achievement in tangible production. The term looms large in the process of granting patents and in litigating them in the federal courts. In published form it is expressed in the two million patents granted in this country and the three million foreign patents, as well as in libraries of thousands upon thousands of technical books and periodicals. The untold millions of facts expressed in these publications comprise the record of prior knowledge and act as a determinant of the novelty in an alleged invention. Upon this evidence, the Patent Office proceeds and the courts decide. The patents in classified arrangement form the vital part and the bulk of the "state of the art" and are not only the foundation stones of the patent system, but offer by far the most comprehensive display of the present state of our industrial complex and the most accurate historical record of its progress.

Patent literature discloses wasted endeavor as well as assured accomplishment. Much ingenuity, hard intellectual labor and protracted effort, not to mention untold expenditure of money, have gone into futilities, into misdirections, before the proper clue to a successful approach was discovered. Almost every art shows such periods of vain endeavor, of error in principle, that preceded the basic invention that gave proper direction to subsequent progress. A case in point is the linotype. Hand composition of foundry type, with its limitations as to output, the waste of time and effort in distribution and other irritating ineffectualities, was known for over a century to be an anomaly with relation to the advanced status of the rest of the art. All sorts of efforts to speed up the process were attempted, resulting in mechanical expedients that were nothing short of extraordinary. Such was the Paige composing machine, probably the most intricate mechanism completed by one man in all history. Mark Twain sunk several hundred thousand dollars in the invention, which when patented was disclosed in a document containing 163 sheets of drawing, 471 figures and 55 pages of printed text. It endeavored to simulate the complex movements of hand composition. But the solution of the problem was not in that direction or through any mechanical means for the selection of individual type. Even when the thought is grasped that is the kernel of successful development, failure may result if its essential embodiment is not discerned. Such was the origin of the linotype. The first thought was the idea of impressing a mold with type characteristics. It failed in practice. Mergenthaler started from that point and derived the essential element that required incorporation in the successful machine. Here, failure pointed to success, and the well-known individual brass matrices, selected by keyboard action to form a line of mold characters, was the result.

Other instances can be cited. The first effort to propel ships by steam simulated the action of hand-operated oars; the successful airplane was preceded by contrivances imitating the flapping of the wings of birds; and the first successful automatic railroad car coupler came after hundreds of contrivances were patented that followed the line of intellectual least-resistance. The course of inventive progress is shown in these two million patents. They form an impressive panorama of the evolution of our material civilization. If they picture strivings that resulted vainly, they also depict attempts which led to fruitful performance. If they show ideas of indecisive nature, many of them indicated the germ that formulated the principle

of the successful invention. They also tell the story of the rise and fall of endeavors and industries as the automobile era outmoded the horse and buggy age. In any event, the grant of patents acts as an incentive to inventive productivity, which typifies our present civilization as truly as the cathedral builders of the thirteenth and fourteenth centuries reflected that era, or the fine arts the succeeding centuries of the renaissance.

This leads us to consider the so-called "lost arts" of the ancients. There is little authority for much of such belief. But right before our eyes we see the process of arts becoming "lost" actually going on. Obsolescence indubitably follows invention, making for a new economic set-up. It would be suicidal in a competitive society to retain outmoded and relatively uneconomic processes and mechanism. Particularly is this true in machinery replacements for manual operations. Not that the latter is "lost" to knowledge, but that they are no longer needed in practice. These superseded arts, especially in the way of doing things, are typified by the "horse and buggy age" which has been so much emphasized through replacement by the automobile era. Almost everything typical of that age has become a discarded art. The very road over which the buggy rolled has given way to a pavement of radically different manufacture and characteristics, absolutely required by the demands of automobile traffic.

The reciprocating steam-engine, the initiator of our mechanical civilization, is itself being junked to make way for the turbine and the Diesel engine as a source of convertible power, and the electric motor for direct application to stationary machinery. In a more humble capacity but of more general experience, we can point to shaving with the old-fashioned razor, outside of the barber shop, as a "lost" art. So through mechanical means are becoming many arts in the household, whose mistresses "find" time to acquire new arts for the exploitation of their acquired leisure. The instances may be multiplied *ad lib*, most of which are known to the general reader, and further examples need not be cited.

The intimacy of our material progress and patent activity is not generally appreciated. Hardly any change due to invention but what is recorded in this "state of the art"; and hardly any advance in the applied sciences which have so vitally changed our whole economy that is not the subject-matter of patent protection. How rapidly that advance proceeds is illustrated in a late report of the U. S. Steel Corporation, which records that $280,000,000 was written off as recognition of the obsolescence of machinery and equipment the last few years. This is a striking instance of how progress marches on. An extensive program of construction and rehabilitation in view of such obsolescence will be required.

Another instance of this kind is given by B. C. Forbes, the well-known economist, who cites the report of Thomas J. Watson, president of the International Business Machines Corporation:

> To-day more than 95 per cent. of our profits are made from things developed in our own engineering department. Last year we were issued 81 patents carrying 803 claims. Our total patents now aggregate 874, with 10,134 claims. We have spent $9,200,000 on development and patents in 22 years, and last year our expenditure in this respect was the largest in our history.

There is such a large demand from patent attorneys, inventors, manufacturers, research institutions and technical government bureaus for copies of these patents that Uncle Sam keeps about 50,000,000 of them for sale and disposal constantly on file in steel cases covering over 35 miles of shelving, of a design unique to this country, for rapid and accurate disposition and economical and clean storage. They comprise the infor-

mation which forms the basis for new ventures, for the extension of manufacturing plants and for the security of existing industries, as well as the working tools of the Patent Office examining force.

We readily perceive, then, why the division into groups of this record of the "state of the art," mostly copies of patents, is a critical concern for the ascertainment of the facts it contains. Practices in other activities offered no examples that could be followed in the unique conditions presented. The broad principles of classification known to the logicians as far back as Aristotle have been adapted where applicable. The biological sciences, where classification was developed to the most amazing extent, provided no model, although we must marvel at the results of modern nomenclature with its swift capability of ascertainment of specific characteristics leading to definite identity of myriads upon myriads of species into which all organisms are divided.

The original scheme of classification followed the lines of least resistance, the patents being arranged in accordance with their relation to particular trades or industries. Jefferson, who first administered our patent system, laid down the rule that a new use of an old machine does not constitute an act of invention. Nevertheless, a new arrangement of old parts may. That is why any division along accepted trade requirements does not constitute a complete standard for purpose of Patent Office examination. Many devices which the public will generally recognize as constituting distinctly different mechanisms, applied to different pursuits, will be held analogous by the Patent Office and the courts because composed of the same association of parts, operating under the same principle of action and producing similar results, proximate if not ulterior. In response to this theory, machines for agitating liquids, for washing and for churning may be held identical; so may an apparatus for mixing air and gasoline vapor and one for mixing illuminating gases having the same structure and operating under the same physical rules. Fluid motors, pumps and meters offer other examples of identity. The law, as laid down by the federal courts, takes no account of ultimate motive, of purely mental figments, but only of the effective elements that combine to produce the result. That is why classification frequently cuts across some of the established lines of industrial distinction, because it would be impossible otherwise to perceive what is "patentably novel" in a complex cosmos of mechanical elements, materials, performances and devices capable of being assembled through permutation and combination into an unlimited number of associations detectable in many diverse industrial arts.

This discussion may seem an abstraction, but is real and vital enough to the profession. To give a concrete illustration, contemplate the organization of an automobile. We perceive the transmission gear, also useful in lathes and machine tools generally; batteries and dynamos, used in generating current for lighting, heating and power purpose; and the body, the wheels, the windows and the chassis, which may include elements common in railway cars, building structures and ventilation; or its ancestor, the locomotive, in which the boiler, the engine, the valve-gear and other accessories, are found to be essentials in all steam-engineering activities for stationary and marine installations. In all industrial applications there are included elements having analogous associations in various other industrial pursuits, and there is no end of interrelationship and extensions, making it scientifically impossible to restrict the operations and influences of inventions within the confines of pigeon-holes limited to the lines of trade boundaries.

Having become conscious of the scheme

considered to be appropriate for patent classification, it is enlightening to look into a few of its applications. It will be perceived at once that any conception arising out of general knowledge, no matter how wide and deep, of the variations in any class of subject-matter that may be patented is astronomically distant from the mark. Let us consider first the recently reclassified class of machine elements—the "phrases" and "clauses" of machine assemblies. It is officially defined as "Mechanical combinations, constituting portions of machines, and consisting of two or more fixed and movable parts so combined that the motion of one compels a completely controlled or constrained motion of the others according to a law of operation inherent in and depending on the nature of the combination." There are over 600 subclasses, the main ones being "Mechanical movements," "Gearing" and "Control lever and linkage systems."

The gear in art and design has symbolized the machine for years, but the automobile has accentuated its function more than all previous agencies in history. It has introduced refinements and new operations that are bewildering in range and intricacy. Only a tour through the mazes of patents in this distinctly small portion of all the mechanical arts can give one a fair idea of this ultra-modern development. It comprises about one half of the sub-classes under Machine Elements. The group of species under the genus "Interchangeably locked" provides the largest assembly, and as partially defined they comprise "Transmissions in which a plurality of speeds are transmitted from one shaft to another by optionally engaging or meshing selected gears or clutches." Any one who has fooled with the insides of an automobile or who has even scanned its illustrated literature has a fair realization broadly of this arrangement, the well-known "transmission." All the more reason will he wonder at the why and wherefore of all this complexity. And yet each species represents clearly defined association of related mechanisms whose common functions are manifested by a single group definition. So while even the skilled mechanician may not place his stamp of recognition on the title of the highly specific subclass 367, the Patent Office has found it essential for economy and certainty in making an examination to create it, which reads in full: "Gearing, Interchangeably locked, Slidable keys or clutches, Single clutch shaft, Progressive, Single key, Reversible driver one way driven." That he may test his powers of comprehension let him read the official definition: "Transmissions which may or may not permit of a change of speed and wherein a plurality of shafts have constant mesh gears mounted on them, the gears on one shaft being rotatable thereon and being adapted to be clutched to the shaft by means of a single slidable key or clutch, this key or clutch being shifted in opposite directions according to the direction of rotation of the drive shaft."

It is not intended to make even a superficial analysis of this class, much less to make any sort of descriptive attempt of the remaining 300 classes comprising the total patent literature. It will be enough if some picture of a small specimen of the entire scene be apprehended so that an impression may be received of the unique character of patent classification, its intricacy and vast scope, some of its picturesque aspects and its departure from accepted concepts. In the examples of subclasses above given, the series in descending scale from the most comprehensive genus to the most limited species is made complete. There is thus exhibited the refinement that classification sometimes has to undergo and the fidelity to the ancient principles of division that is maintained once the group is segregated. And all this because the patents representing

even an industrial art have developed not necessarily along the lines of trade cleavages but frequently in directions totally at variance with them, making it essential to mark out these tendencies as standards with which contemporaneous efforts may be compared. Of course, if tendencies take new directions, as is constantly the situation, the classification takes cognizance of them by appropriate amendments when the new patents depicting the new aspects become available.

A further consideration vital for classifying is the psychology of the inventor, which urges him to a mental approach to a problem which defies preconceived analysis based merely upon what is customary. What association of mechanisms or functions he may exhibit or what particular directions his fancy may take, is impossible to predetermine. To arrange all such possible mental patterns in advance of their exhibitions so that they can fall into natural groups, or even to do so after they become disclosed, is a problem not present with anything like the same difficulty in any other line, scientific or practical.

An example is the newly reconstructed class of cutlery. There are 63 main points of contact with other devices, such as it would be impossible to conceive of by others than those highly specialized, endeavoring to cover thoroughly a field of almost limitless extent. A glance through the list of arts contacting this one in which it is discovered there are common features discloses such diverse devices as "Compound Tools," "Abrading Machines," "Quarrying and Ice Harvesting," "Gear Cutting," "Butchering," "Roads and Pavements," "Leather Manufacture," "Farriery" and "Label Pasting and Paper Hanging." The interrelation of the arts, their interdependence and the difficulty of attaining any sharp demarcation are thus convincingly exhibited.

This is also well illustrated in the rapid development in recent years of inventions in razors. Less than 15 years ago, only two subclasses were found necessary to divide this art. A little more than a generation back this cutting implement was known to the generality of observers only as a wicked-looking, ultra-sharp, concave-edged blade with a swinging handle in a constant state of unequilibrium. It was dangerous enough to the innocent novice when used for its legitimate function, but carried implications of more serious import when otherwise wielded. To-day, in the search for safety, comfort and automaticity, it takes about 70 groups to properly arrange its various manifestations. Some of the possibilities so recognized, although absolutely unfamiliar to the "boss barber" of the preceding generation, are razors combined with means which permits the sharpening of the blades; in which a magazine holding blades is incorporated in the instrument; or provided with arrangements for collecting waste, such as lather or hair; or for cleaning the razor; or for vibrating the cutting edge; or for giving motion to the blade by frictional contact with the shaving surface.

Some of the classes conform in title and subject-matter to public conception. Dentistry is an example, and a glance through its list of 71 subclasses will recall to the sensitive sufferer many an instrument of torture or many a torturous moment. And yet the searcher for comprehensive information is further directed to a variety of conflicting or complementary devices. It is difficult at first to learn why he should have to scrutinize the class of "Brushing, Scrubbing and General Cleaning," which picturizes boot-blacking appliances, street-cleaning apparatus and vacuum cleaners, but that is where he has to look to find what is old in tooth-brushes. So it is for tooth-picks and dental cuspidors, which are respectively classified under "Toilet" and "Baths, Closets, Sinks and Spittoons."

Allied to dentistry is the official class of surgery. The array of murderous-

looking instruments and mysterious appliances and applications in that class are even more pronounced. Under "Diagnostics" we perceive "Specula, non-pivoted gags"; under "Orthopedics" we find "osteal adjusters"; "Bandaging" provides a generic supply of many features relating to "Fracture apparatus"; "Trusses" are of greater variety in appearance and function than any common garden species of citizen could possibly comprehend; "Medicators" include "Syringes" provided with mechanisms actuated by screws or racks; while the branch of "Instruments" comprises enough appliances to cut, shear, saw, puncture, abrade, rasp, squeeze, compress, distort, fracture, dislocate, relocate, dilate or agitate any anatomical or sensitive feature of the human body to an extent not approached by the unrefined devices shown in the Nuremburg torture chambers displaying the most efficient practices in the administration of medieval justice.

A notable recognition of present-day highly specialized activity is the establishment of the new class of "Chemistry, Fermentation" with 146 subclasses. It has broadly to do with a chemical change caused by an enzyme functioning catalytically. Illustrative of its character is the full title of subclass 46: "Ultimate processes; Carbohydrates, fermentation of; Fermentation to non-carbohydrates; By bacteria only; Butyl alcohol and acetone production; With preformation of ferments therefor; Acclimatization or immunization of ferments." This class, however, does not exhaust all biochemical activities, for others of which we are directed to "Plant Husbandry" for sprouting or germinating seeds for planting; to "Fertilizers" for fertilizers that contain bacteria; to "Foods and Beverages," for alcoholic beverages, malt extracts or other "alimentary" compositions that contain bacteria; and to several other classes where bacteria or ferments are utilized.

Every one is cognizant of the rapid development of the airplane. The Patent Office officially recognizes the same in its recent recasting of the class of aeronautics. In its superseded form there were 31 subclasses. The present arrangement provides for 155 subclasses in that class. A glance through them visualizes at once the changes that have taken place since the Wright Brothers were first active and the extremely technical nature of that advancement. Under "aircraft sustenation" are perceived fuselages and struts arranged to act as "sustaining airfoils" and various designs in the structural parts to alter the amount of lift or to vary their effect responsive to changing conditions. Propulsion, steering and power plants having special relation to aircraft navigation are recognized, especially with regard to the tilting of the aircraft and for high altitude purposes. Then, many patents are grouped under "Aircraft control" in which automatic devices are used and which provide for ballast regulation and buoyancy variation. Landing gears, brakes, special structural features and safety devices galore are also enumerated. And contacts with many other arts are indicated, proving the lack of self-sufficiency in all the arts. The frame work, windows, insulation; the power plant; and the rudder and steering devices have many features in common with building construction, vehicles, marine propulsion, internal combustion engines, power plants and ships.

Scattered throughout the patent literature are many frivolous and ridiculous "inventions," but proportionately they form a minute percentage. The great bulk of the patents are granted on serious, meritorious, practical attempts to "advance the state of the art." Even toys may be included in the latter category, some of which exhibit mechanical expedients calling for ingenuity amounting almost to genius.

Reminiscences of the days when

square-riggers dominated the seven seas arise in scanning the classification of "Ships" in such salty-sounding terms as "Cringles and Hanks"; "Clews and Thimbles"; "Bitts, Cleats and Pin Rails"; and "Spikes, Pins and Fids." Acoustics provide in part that sound waves be propagated under conditions of favorable receptivity so that the sound may be distinctly heard, and then under contrary conditions in the subclasses of "Mufflers," which are officially described as "devices for attenuating sound."

Recollections of earlier customs are also induced by an inspection of the last-named section of the variegated class of "Baths, Closets, Sinks and Spittoons." Except for a few of the 28 subclasses directed to this group of spittoons, this is a dying art. There is some activity in dental lines and in so-called pocket or paper receptacles. Some of the subclasses relate to devices laid in the floor and having rather complicated piping for flushing. A peculiar subclass comprises a few patents for association with a bar providing a community service for the expectorating customers. Although the pre-prohibition era has been revived, patents for this relief appear no longer sought for. Most of the patentees in this group use the more delicate term "cuspidor" for the plainer official title.

The recently reclassified class of "Metallurgy" shows its highly advanced state as merited by its primary character and the immense amount of ingenuity that has gone into its development. Nothing could be more modern than its electro-thermal processes nor bolder than its gigantic stack and refining furnaces; nor more delicate than its processes for production of alloys. Here are temperatures reached undreamt of before this age and comparable to that on the surface of the sun, simulating conditions present in the convulsive processes of nature in the creation of primeval products.

An interesting class recently formed has the graphic title of "Medicines, Poisons and Cosmetics." This is, like a few others, a heterogeneous class of several distinct groups. Whatever implication of relationship between them is suggestive to the active imagination is not intended officially to exist. The poisonous ingredient, if any, in the medicine is obligated to cure and not to kill; the active principle in the second group is mainly for destruction; while the third is primarily for beautification of the person. Any device or preparation utilizable only for destruction of the human species and having no counteracting effect of preserving order or maintaining national security is considered to be without utility, and as such is not patentable. That is why the subclass of "Animal poisons" is not given its broadest biological meaning but is restricted to non-human beings, such as rodents, for example.

Butchering is a class that will surprise the uninitiated. It includes among its 45 subclasses such devices as machines for removing scales from fish, beheaders for fowls, instruments for making tough meat tender, in which the recalcitrant product is pounded or otherwise coerced into a state of edibility, and appliances for forming sausages into some sort of "linked sweetness," more officially termed "chain form."

Agriculture, our leading pursuit, is especially well represented. There are classes of "Harrows," "Plant Husbandry," "Planting," "Plows," "Harvesters," "Animal Husbandry," "Bee Culture" and "Dairy." The most ancient of implements is the sharpened stick for prodding the earth into productivity. For many millenniums its design remained unchanged. But to-day its modern prototype, the plow, and associated cultivators and implements require 245 subclasses, embracing almost 22,000 patents, to illustrate "the advance of the art."

The art probably the most "caviare to

the general" is that of "Chemistry-Carbon Compounds," with 173 subclasses. It abounds in weird names and stranger formulae. Dyes form its principal branch. The subclass 75 title, as an example, should be scanned lingeringly to avoid superficial interpretation of its import. It reads: "Diazo, azoxy, nitroso, azo, hydrazo—Trisazo—Diaminodiphenyl—Benzidine—Carboxylic." Peculiarly, the lines of division here follow more acceptably cleavages apprehended by commercial technicians, making the groupings more analogous than in the simpler arts.

The most formidable of the mechanical arts have not been touched upon. Textiles, printing, glass-making, threshers and harvesters, adding machines, metal working and many labor-saving devices are complicated beyond the imagination of the most advanced engineer of only a few generations ago. The directions of their advance and the significance of their performances could only be detailed by specialists in each branch. When it comes to electrical and chemical applications, with their adaptability to so many new services and their eerie capacities to achieve almost miraculous results, a different but equally difficult task is confronted.

Before 1868, less than two classes out of 22 were devoted to chemistry and none to electricity. In 1872, a single class of electricity was created out of 145. To-day, about one third of the examining divisions specialize in the chemical and electrical arts.

The range of all the arts has not been indicated here. Things as simple as a hairpin or as ponderous as a cantilever bridge, and as various or antipodal as perfumes and explosives; dynamos and electric bulbs; dams and canals; tents and steel structures; rafts and submarines; refrigerators and furnaces; toy pistols and heavy ordnance; watch springs and newspaper printing presses; not to mention the processes for manufacturing insecticides and fertilizers; or for extracting metals or making dyes—all these subjects in the most refined differentiation are represented in the 5,000,000 U. S. and foreign patents, 35,000 subclasses and 300 main classes of the Patent Office files.

One may almost acquiesce in the conclusion that "there's nothing new under the sun" upon realization of what this vast literature contains as to man's accomplishments. Everything is there except the philosopher's stone and perpetual motion. And yet every year sees new accomplishments making obsolescent the wonders of a previous generation.

ARMY ANTS IN CALIFORNIA

By ARNOLD MALLIS
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ONLY an occasional lamp with its attendant circle of mellow light rippled the dark calm that pervaded over the college in Davis, California. On this July night, as on many previous nights, armed with a cyanide jar and with a vial of alcohol, ready to cope with giant long-horned beetles, huge electric-light bugs or with our special delight, winged ants, we commenced the rounds of the deserted campus. From pole to pole we maneuvered our pedal extremities, but in vain did we seek to appease the palate of our ever-clamoring cyanide jar. Finally a long line of ants scurrying across an illuminated area momentarily attracted us. A second glance, more careful than the first, did not return so barren. These could not be the ubiquitous Argentine ants, omnipresent in our walk, in our garden and in our sugar bowl; the hurried gait, the nervous antennae, the swift pace were all unlike them. And then we were electrified with the realization that here, before us, on this soporific agricultural campus, was the true sovereign of the jungle, the army ant, *Eciton*! Without delay, our dog-eared and ever-patient notebook commenced to delineate the peregrinations of these fascinating ants.

In a darkness that was dissipated by occasional lights, these nomadic meat-eating ants were to be seen moving along the curb on both sides of the street in trails that were some forty to fifty yards in length. Once, one trail was sighted that must have extended for more than one hundred yards. Diagonal and irregular trails connected the hurrying columns on both sides of the street. The ants moved for the most part in single file, and infrequently we would observe five or tên ants abreast, making a loose column some one or two inches in breadth. These columns would attenuate to files of single ants, which ultimately broke into scatterings of ants that hunted individually. In these trails, the ants marched in both directions. Some species of ants flow along like a drop of water down a pane of glass; other species of ants jerk along like a horse and cart in traffic; and the army ants, apparently the neurotics of the emmet world, presented a very agitated appearance as they traversed the terrain, this being augmented by the nervous movement of the antennae which constantly palpated the ground. Closer perusal of these reddish and greasy ants revealed the fact that the constantly vibrating antennae displayed a whirred effect not unlike an electric fan.

Moving across the ground at a rather animated pace, the ants individually covered a foot in approximately ten seconds, and an entire column would advance some seventy-five feet in one hour. Upon arriving at the head of an advancing column, we observed definite pioneers or trail blazers, and these, as soon as they were separated from the main body of the column, would turn about and run back approximately one inch, and then once again hasten to the trail blazing. Thus the head of the advancing column was not unlike an arrowhead, with a tip that advanced and sides which retreated.

Since reportedly these ants do not discern too closely the source of their meat—be it entomologist's ankle or grasshopper's genitalia!—the observer became

interested in finding what effect if any a 50 per cent. sugar solution would have upon them. When a one-half inch smear of this sugar solution was placed in their trail, it so definitely disconcerted them that they immediately turned back on both sides upon contacting it. They apparently did not detect the presence of the sugar solution until they ran into it with their antennae. Mere water when smeared across their trail would also disturb them, but after a few minutes they would cross this smear.

The predilection of these ants for concentrating in lighted areas was in all probability due to the great numbers of insects that were attracted here and upon which they preyed. In fact, the army ants returned nightly to certain lighted areas to capture their insect victims. With the ferocity of a wolf pack, the ants leaped upon any insect that moved within reach of their rapacious jaws. Individually or en masse, they would seize their prey and endeavor to drag it along, meanwhile curling the abdomen so as to sting. Once they were attached to a limb of their captive, only the most violent exertion on the part of their prospective victim could shake them from their grip. Any living creature that remained immobile was not molested, as for instance the click beetle that was ignored when it played possum and then was attacked immediately upon moving. A caterpillar that came into their path noticeably recoiled with each sting. Ground scavenger beetles, mayflies, water boatmen and crickets appeared to be favorites on their menu. Each night the ants could be found returning with their insect prey to a small slit between the grass turf and the curb. Yet strangely enough, when this same spot was probed during the day, no ants were to be seen.

Some of the ants were picked up and placed in a few glass vials. One of these vials was accidentally broken, and upon stoppering it with the palm of the hand, the ants commenced to bite rather severely, but they did not sting. These ants were then placed in a bell jar, and within a few hours they formed a complete moving circle around the sides of the jar. They continued to walk in single file and in twos for more than twenty-four hours. The following day many of the ants were quiescent. Some of the workers had various stages of immature young in their mandibles. One of the army ants, by means of her mandibles, grasped a larva just behind its so-called head region, the larva being held between the legs of the army ant so that the ventral side of the larva was next to the ventral side of the ant. Another of the captive army ants made repeated efforts to remove the larva from the care of the first army ant. These greasy-appearing ants spent much of their time licking one another's legs and antennae which they would do in a very deliberate manner. The ant being licked would placidly fold its legs, and lie on its side. Some of the ants that fell in an improvised moat recovered in one minute, after being placed on blotting paper, from a wetting of approximately twenty-two hours.

In this, our hour of need, we could neither borrow nor purloin a flashlight, and thus it was with some difficulty that the trails of these hurrying ants were followed when they traversed the dark expanses. While following one of these barely discernible trails along a curbstone, a sudden thickening of the single file of ants was noticed; this then enlarged itself into a very compact phalanx some two inches across. Obeying a hunch, and with various misgivings anent our future physical comfort, we plunged our fingers right into the center of this compact body, and like the celebrated Mr. Horner, extracted a plum,

the queen, a most rare and delectable specimen, indeed! Many workers were attached to various portions of the queen, and these, observing their decorum, made no attempt to sting us now or at any other time. Needless to say, when the queen and the workers were placed in a vial, the workers became very excited, particularly as displayed by the constant vibratile motion of their antennae. The workers by means of their mandibles commenced to excitedly rake the sluggish body of the queen, and even gave one the impression that they were biting her. Sluggish and quiescent, the greasy-appearing queen would rest her elongated and heavy abdomen upon the ground, meanwhile feebly twitching her antennae and tarsi. At other times the lubberly and matronly queen would vibrate her antennae, and with her tarsi feebly paw at some blotting paper. The workers were wont to attend her at all times, and with open mandibles they would feel the anal end of the queen as though they would appreciate an egg; however, this lady was never observed to partake of her queenly prerogative of laying an egg. The spectacle of numerous army ants parading and standing upon their comparatively huge queen while she rested upon her side was not without its humor; perched thus upon the queen, they would lick her body and appendages. Some alien larvae and pupae that the army ants had captured were piled upon a sponge adjacent to the queen. During the entire time that these ants were observed, they were never seen to make any attempt to eat these immature forms. This interesting queen, much to our regret, expired some five days after her capture. This may have been due to her being inadvertently submerged the previous day in a water moat; or to the environment, irksome to so regal a being, her soul departed.

On the second night after first sighting the army ants, while prowling about with our proboscis close to the ground, not unlike an aard-vark, we encountered a sight that held us spellbound for many hours thereafter, for there before us, spread out for a distance of ten feet along the curbstone, and barely perceptible in the darkness, were thousands of dead ants, many piled in heaps. Most of the ants strewn across this battlefield were blackish in color, and since the army ants are reddish, it could be roughly calculated that there were ten times as many dead black ants as there were dead red army ants. Imagine our surprise when we later ascertained that the dead black ants were those well-known aliens, the European pavement ants, *Tetramorium caespitum* (Linne). The combatants had evidently retired, and now the dead ants dominated the scene. A few living pavement ants were hauling the deceased and disabled from the nest, the latter revealing themselves by the feeble twitch of a leg or antenna.

Two days later, at 8:30 in the morning, when the sky was overcast, and a few drops fell, the army ants were observed on the march, and were seen to carry the immature forms and the adults of the pavement ants. That same evening we lowered our frame into the grass, stretched it in a horizontal position, adjusted our optical system accordingly, and now fortified with a flashlight, we focused same upon the scene of combat between the reddish army ants and the blackish pavement ants. If the number of dead scattered along the curbstone was any indication of the progress of this particular battle, then it must be stated that honors appeared to be evenly divided. The way of the red invader was strewn with thorns, for the blackish army ants would "gang up" in twos to sevens upon an army ant, seize her appendages and then stretch them to all points of the compass. Some pavement ants were car-

rying disabled army ants from the field of honor only to dump them unceremoniously upon the curbstone, or upon the heaps of ant-dead. How fiercely the battle had raged could be readily attested by the great number of ant mounds distributed along the water pipe.

As the evening grew older, some of the savage army ants were observed carrying the captured larvae and pupae between their legs so that the venters of both adjoined; a few of the ants conveyed callows. One army ant was bearing an adult pavement ant that was apparently dead; it lacked antennae, and one node of its petiole was practically separated from the other node. It appeared as though every other reddish army ant carried some form of pavement ant.

At approximately eleven o'clock that same evening, some two and one half hours after our first observations, we returned to the water pipe along the curb to once again survey the scene of the military engagement. Hostilities had noticeably subsided; here and there a red army ant and a black pavement ant were still engaged in mortal combat. No longer having to concern themselves with their enemy, the black pavement ants were now engaged in removing from the nest the dead and dying combatants, whether red or black.

What of the army ants and the living booty that they had plundered from the nest of the pavement ants? Following these we soon came upon a strange sight but a few feet removed from the battlefield. On each side of a vertical groove in the curbstone hundreds of army ants were grouped in an irregular body three eighths of an inch wide and two to four inches long. The mass of army ants on either side of the groove, immobile except for their moving antennae, grasped the larvae and pupae of the pavement ants in their mandibles. Other army ants moved in a cleared furrow between these living walls. Evidently this assemblage about the groove was a temporary storage ground for the captured pavement ants. Some five feet further along the curbstone around a similar groove, pupae and larvae were assembled in a mound upon which the army ants were gathered; two similar accumulations were encountered within the next eleven feet. A number of small black mites were present wherever the army ants were thus aggregated. Having duly captured their victims, the army ants were engaged in conveying their captives to the other side of the street.

One and one half hours later, but one cache was to be found, and this one some fifteen feet from the scene of the battlefield. Additional observations at the site of the battle disclosed the fact that the blackish pavement ants would not hesitate to hasten to the attack, many of them carrying off army ants by their own individual efforts. Bulldog-like in their tenacity and valiant in the face of their advancing foe, they would move forward to grapple with the fierce army ant. Quickly would they dart and endeavor to seize the long mandibles of the army ant. Failing this they would grasp a limb. The army ants would endeavor to sting, and then both ants would coil their abdomens as though they were applying their abdominal stilettos. At times, in the ensuing melee, four to five army ants would rush to the aid of their embattled sister, and would then seize various appendages of the pavement ant. One army ant was observed to clamber upon a pavement ant, place its mandibles over the neck region of the pavement ant, the latter then being rendered *hors de combat*. An innocent bystander, *Dorymyrmex pyramicus* (Roger), a common dark ant hereabouts, concerned with other matters, would hastily scurry from the path of any army ant it inadvertently contacted.

Now the war had risen to the very heights of fury! The killing was done with great dispatch and quite neatly, with none of your crimson gore to mar the martial scene. Here, a black pavement ant, pegged out like a circus tent, its appendages taut as violin strings, would be in the center of a circle of tugging red army ants; adjacent, a red army ant, the hub of an encircling body of black pavement ants, was being drawn and quartered in the most respected manner of the Inquisition. Two pavement ants made fast to an army ant, one seizing the mandibles, the other the hind femur; fighting savagely, desperately, the red army ant finally wrenched itself free. There, an army ant unconsciously displayed her warlike prowess; her black victim fastened to her limb, refusing to yield even to Death! Locked in combat, the warring individuals would strive to seize the mandibles, a vital hold; at one and the same time they would curl their abdomens beneath them, evidently for leverage, for protection and in order to sting.

The army ants continued pouring their red hordes into the nest; and the pavement ants fought valiantly and unflinchingly against the invaders. But despite this, the army ants emerged triumphant from the nest bearing the fat larvae and pupae of the pavement ants in a constant conquering stream. Yet, individually, in ant-for-ant fashion, the black pavement ants appeared quite capable of coping with the red army ants. It must have been sheer numbers, the vast inpouring of the army ants into the nest, which made it possible for them to overpower the pavement ants. In defeat, the army ants would appear entirely exhausted, disclosing their debility by feeble twitch of leg or antenna. This savage invasion and implacable war raged for three nights, having undoubtedly commenced several days previous to our first observations.

The following night there was no evidence of fighting, but two mounds were found that contained several hundred larvae and pupae of the pavement ants. Both caches were well attended by the army ants, and two crowded trails led to these mounds. The army ants were then engaged in carrying the larvae and pupae into the crevice between the curb and turf which appeared to be a provisional nesting site.

On the next evening the army ants again emerged from the area between the turf and the curb, a crevice that had been closely inspected during the afternoon, and which was at that time barren of army ants. Three caches were seen, each of which was covered by several hundred army ants. The immature forms of pavement ants were to be seen in one mound. When this was disturbed by flashlight, the army ants commenced to remove the young, carrying them between their legs in the previously described manner. Whenever annoyed by the flashlight or by being breathed upon, the army ants would raise their bodies so that they inclined sharply forward, or were almost vertical; the abdomens would be curled beneath as though they were sitting on them, the front and middle legs would be rigid, the hind legs bent, the mandibles widely opened, and the quivering antennae would inquire outwards.

Coincidental with the marching of the army ants was the emergence of thousands of tiny thief ants, *Solenopsis molesta validiuscula* Emery, the workers, the males and the queens. Intense was their excitement, for the nuptial rites were to be performed, the mating flight consummated. No respecters of holy matrimony, those coarse barbarians, the army ants, would seize the brides

and grooms, and carrying them by the side, they would hustle them off to serve as the "piece de résistance" in some ant banquet. Not one to stand idly by while such sacrilege was committed, the pale yellowish tiny thief ants would seize the army ants by the legs, mandibles and terminal portions of the abdomen; the latter evidenced their displeasure by vigorously curling their abdomens and endeavoring to sting. In this case, as with the pavement ants, resistance was entirely futile.

For seven nights we had been on the trail of these marauding army ants; on the eighth night they were gone, apparently having vanished into thin air. Approximately one month later, we once again blundered upon them, this time in broad daylight, some fifty feet from the area where we had first made their acquaintance. They were marching over a somewhat moistened and shaded area, and apparently had just pillaged a nest, for they were conveying larvae and pupae which appeared very similar to those of *Tapinoma sessile* Say, the odorous house ant. We sighted them in the morning some two days later, in the same locality, and this was our last tryst for many months to come. Although the army ants had gone, they had left in their place an unsolved enigma, namely, could they "lick" the Argentine ants, emmet champions of the Davis campus, and omnipotent conquerors of all ants who dared resist their roll of empire? We had seen the army ants vanquish foes who had opposed them with crushing mandibles and darting stings; we had seen the Argentine ants dismember their opponents, limb by limb. In a clash between the army ants and the Argentine ants, upon whom would the gambling gentry place their odds?

Nine months followed each other into oblivion, and at 8:30 in the evening of April, 1936, our respective orbits crossed once again. At the base of a lamp post, that red scourge, the army ants, were busily engaged in overwhelming carabids of a small size. With the expenditure of much energy and the accomplishment of little progress, the army ants were occupied in dragging their victims away from the lamp post, and were hindered by some of their sisters who believed the prey should go in the contrary direction. The army ants then occupied all the area about the base of the lamp post. Upon returning at ten o'clock the same evening, it soon became evident that the "status quo" had been radically altered. The army ants now occupied but one half the area about the base of the lamp post; the Argentine ants held the other half. For the first time the army ants were on the defensive, and the Argentine ants had decided to contest their rights to the hunting grounds at the base of the post. A rough triangle of army ants, with the apex foremost, faced the Argentine ants, the number of ants in this triangle varying from time to time from twenty-five to fifty ants. Now that the army ants were in battle formation, they were immobile, watchful and expectant, with their antennae extended at right angles to their heads. Behind this triangle stood other army ants in the peculiar position previously described; abdomen curled beneath, hind legs bent, front and middle legs stiff and rigid, the body proper inclining forward at a forty-five degree angle, there being some five or six ants in this strange position of watchful waiting. For a few inches outside the apex of the guardian triangle, a "no man's land" was to be found in which army ants were embattled with the Argentine ants in ant-for-ant combat. The Argentine ants utilized the usual attack, pulling and tugging at the appendages of the army ants. At times, an Argentine ant would penetrate this guardian triangle that protected the orderly retreat of the

army ants. Sometimes this would cause practically no commotion, but at other times the army ants would rush savagely for the Argentine ant. Slowly the army ants retreated from the base of the lamp post into the adjacent grass, protecting their rear-guard with the redoubtable triangle. And behind this protecting triangle, the army ants were busily engaged in dragging carabids between the grass and the concrete base of the lamp post. At 11:30 that same evening the army ants had practically disappeared from the base, and were now marching into the grass. It was thus that the Argentine ants met the challenge.

Individual army ants when removed from their ravaging armies appeared to be much more mild in temperament. On placing seven army ants together with five Argentine ants in one vial, it was observed that the two species were anxious to avoid each other. Finally one of the Argentine ants seized an army ant by the tarsus of the left hind leg. The army ant while being hurled and dragged about offered no resistance to the Argentine ant; in fact, the only effort the army ant made to escape this persecution was to brace itself with its thick antennal scapes against the glass surface. The other army ants in the vial made no effort to aid their sister in distress, even when close to her. It is difficult to understand why the tormented army ant made no effort to resist, even when it practically had its mandibles around the leg of the Argentine ant. In time the Argentine ant released its hold on the army ant, and then the latter appeared to be in an exhausted and sorry state.

Not content with pillaging the nests of their kind, the army ants, like their ubiquitous cousins farther south, have in rare instances made a nuisance of themselves by invading homes in Sacramento. In all probability, it is only their lack of numbers that deprives them of the respect that their tropical sisters command.

And with this, we bring down the curtain upon a glimpse of ravaging, pillaging, nomadic ants, intriguing six-legged creatures whose limbs are more properly at home in unspoiled equatorial forests and jungles than in the effete Kentucky grass of an agricultural college campus.

A SCIENTIST IN MOSCOW

By Dr. DEAN BURK
WASHINGTON, D. C.

Is there a characteristic Soviet science and scientific spirit? Although the man of science is in many ways the same the world over, it is important to consider him in relation to his fellow-men, whose lives he constantly changes, and to regard him as a member of a given social organism which has attained a particular state of complexity and knowledge. The fact that the background of Russian science, and of Russian culture in general, has been so distinctly different from that of Western countries makes the present rapid scientific development in the Soviet Union an interesting subject to consider from many points of view. On the basis of recent visits to the U. S. S. R. and as an experimental worker in a Moscow laboratory, I shall describe certain aspects of Soviet science and of scientific life as I saw it and took part in it.

Since the revolution of 1917 there has been a ten-fold expansion in the number of scientific institutions, personnel and output of experimental work. A similar but less marked development took place in the United States during the first quarter of the present century. The exceptionally rapid increase of scientific work in Russia has been made possible by a research budget which undoubtedly comprises a proportion of national income as large as or larger than that of any other country. Because of the short time-scale over which this increase has occurred, many laboratories have the atmosphere of a pioneer settlement, with its lustiness and confusion, projects in various stages of construction and general overcrowding. I was walking through one such laboratory with a prominent young chemist, and casually remarked on the large number of workers. "Yes," he said, with a smile, "and confess that you are wondering just what they are all doing."

The large influx of scientific workers may be explained in part by the widespread public interest in science. Science has been characterized by some as the new national religion, and, in so far as the people believe that it is the basis of their present and future well-being, this description is apt. It was upon the occasion of a visit to Russia in 1935, to attend the Physiological Congress, that I first became aware of how general has become the replacement of a belief in God by a belief in man and science. Through the newspapers, which devoted more than half of their space to reporting this huge international gathering, all the big names and events of the congress were made known to the man and woman in the street. For a time, it was surprising to find that many people in walks of life far removed from the scientific were familiar with the leading Soviet scientists, and, in instances, with details of their particular accomplishments.

When the congress as a whole traveled out from Leningrad to Peterhof twenty miles away, in a procession of four hundred automobiles, the entire route was lined with people waving handkerchiefs, and at one point soldiers threw their caps into the air. On another excursion made by a smaller party to the large recreation park in Moscow, a similar spontaneous reception was afforded at the gate by a cheering crowd, which, of its own accord, in a spirit of self-government often encountered, formed a gangway to let the visitors enter. Inside the park, an open-air theater audience of twenty thousand spectators rose to its feet to greet the congress members as they filed in to their seats. This friendly, albeit embarrassing,

demonstration of feeling to the foreign scientists by the general populace reflects, in some measure, the nature and extent of the popularity of science in Russia to-day.

II

At the head of the scientific system of the Soviet Union is the Academy of Sciences, founded by Peter the Great about 1725. After the revolution the academy was taken over by the new government and in 1934 moved from Leningrad to the capital at Moscow. This change was made necessary by the significant position attained by the academy in the planning of the industrial and technological development of the country. The resulting upheaval accounts for much of the disorganization encountered in the Moscow laboratories. Plans for a group of new buildings have been prepared but will require some years for execution *in extenso*. In the meantime, the academy's headquarters have been established in a former palace in the district of the proposed new buildings, and its work is carried on in about a score of institutes nearby. In the past there were forty academicians, according to the French tradition, which Peter the Great wished to emulate; now there are more than ninety.

The academy, working with the Soviet State Planning Commission (Gosplan), is the center for directing the scientific activities of the Union. Through various committees, the economic and industrial needs of the country as a whole are studied, and each year a plan of research is drawn up and apportioned to the different institutes. In the words of Karl T. Compton, president of the Massachusetts Institute of Technology and chairman of the former American Science Advisory Board, "the Academy of Sciences of Moscow has been called upon to aid the government in organizing the great system of research institutes recently created throughout the country and now in progress of doing some of the finest and most progressive scientific work to be found anywhere in the world."

The internal organization of the academy institute at which I worked is typical of that of most places of work in the Soviet Union, whether factory, office, hospital, university or collective farm. A maximum of self-government is achieved in any of these institutions through a system of *triple control* by what is commonly known as the "Triangle," which consists of a member of the administration, the local secretary of the Party and one person from the social unit or trade union. I had excellent opportunities to watch the operation of this characteristically Soviet system of triple control, and, in one particular instance, to follow the course of development of an intricate case for a period of nearly a month as it drew to a climax. A scientific investigation had been pursued by a certain group of workers for some six months with diligence but, as gradually and then finally became evident to fellow-workers around them, with inadequate judgment. In default of immediate correction on the part of the scientific director, the matter was taken up, after much private discussion, by the social group, and finally by the Party, to which the scientific director eventually admitted full personal responsibility for undue laxity.

Various individual matters are handled through the Triangle, such as redress in case of claimed inadequate remuneration or position. It is the great merit of the system of triple control that, however much it might seem upon first consideration to be a case of two cooks too many, it does provide the individual who desires some adjustment with a means of social leverage to bring forward his claims.

THE BIOLOGICAL INSTITUTE OF THE ACADEMY OF SCIENCES, DECORATED FOR YOUTH DAY.

The system of triple control succeeds in providing a good average of objective judgment, with a maximum of dignity, for all parties concerned. Of course, it operates more as a balancing force than executively; for instance, the scientific director generally determines the salary scales and budget allowances within his institute, subject, however, to the possible readjustment indicated.

III

The opinions and wishes of the workers as a whole are made known at innumerable meetings of the political, social and scientific groupings, at several of which I was an interested spectator. Although quite frequent, these meetings were always well attended, not only because participation was expected, but because Russians enjoy talking endlessly over problems real and imaginary, and are perhaps never happier than when they have transferred one of these problems from the material world into their heads. Often a long table was set with plates of cookies, apples and candies, and enormous quantities of tea were consumed, for which literally buckets of hot water were carried in. Emphasis was equally divided, in talks describing the progress of work in the laboratory, between outspoken but friendly criticism and due praise. Following this, the discussion would often turn to more general topics and eventually to the world-wide political situation. I remember in one particular talk that a professor pointed out in connection with discussion of the Physiological Congress that, whereas before the revolution not more than a score of people in the whole of Russia could have taken part in such a congress, one hundred and fifty of the five hundred papers of the congress had been given by Russians, in widely different fields, and, incidentally, in the languages of the visiting foreigners.

At less frequent intervals there were joint meetings of several institutes, at which it was the custom to elect or to appoint a dozen or more temporary vice-chairmen, who would individually and with applause take places of honor on the platform. At one joint meeting which I attended, our laboratory dishwasher sat

THE LOCAL SECRETARY OF THE PARTY
IN AN ACADEMY INSTITUTE DEVOTES THE USUAL SIX HOURS PER DAY TO LABORATORY WORK.

in this capacity by the side of a venerable academician. Each time that she caught the eye of some one she knew in the audience she would blush and appear very self-conscious; she was unmistakably delighted at the honor of being elected. The shared dignity of all classes of workers, in and out of science, was impressive to observe. At a tea-table discussion one day, some one had said to me, "Our ideal is not so much democracy as humanism." I should mention that the dishwasher was a "udarnik," which means in American that, though only a dishwasher, she was an excellent dishwasher.

Upon special occasions, such as nights before May Day or November Seventh, meetings of the entire academy would be held in the large Red Army Hall, which, like the Smolny Institute, the State House in Leningrad, was formerly a school for *jeunes filles*. It was at one of these celebrations that I heard the education of Oxford and Cambridge described in all seriousness as medieval and semi-religious, and the modern Soviet universities compared with them to great advantage. The speaker, a man of seventy, remarked, with a look to his audience for approval, "Even an old dog like myself can change with the times." During the evening there were eight speeches, each fifteen to twenty minutes long, listened to attentively from beginning to end by all, including eighty-eight year old Professor Karpinsky, the late president of the academy. The speakers included, apart from scientists, a well-known author and publicist, the head of Gosplan, the second ranking officer of the Red Army, and another Red Army officer who had just returned from France and who gave a long account of his visit and conversations with French generals. An important member of the Party talked for forty-five minutes, without reference to science, on the history, theory, practice and achievements of the U. S. S. R. since 1917. After an intermission for refreshments, an early one-act play of Gorki was presented, followed by music and a ballet by men of the Red Army, until past one o'clock. During the speeches, the mere mention of a well-known name brought forth tremendous handclapping, accompanied, upon appropriate signal, by music from a loud brass band concealed in an alcove. Each speaker mentioned Stalin, Kaganovitch or Molotov at least once (brass! without signal!).

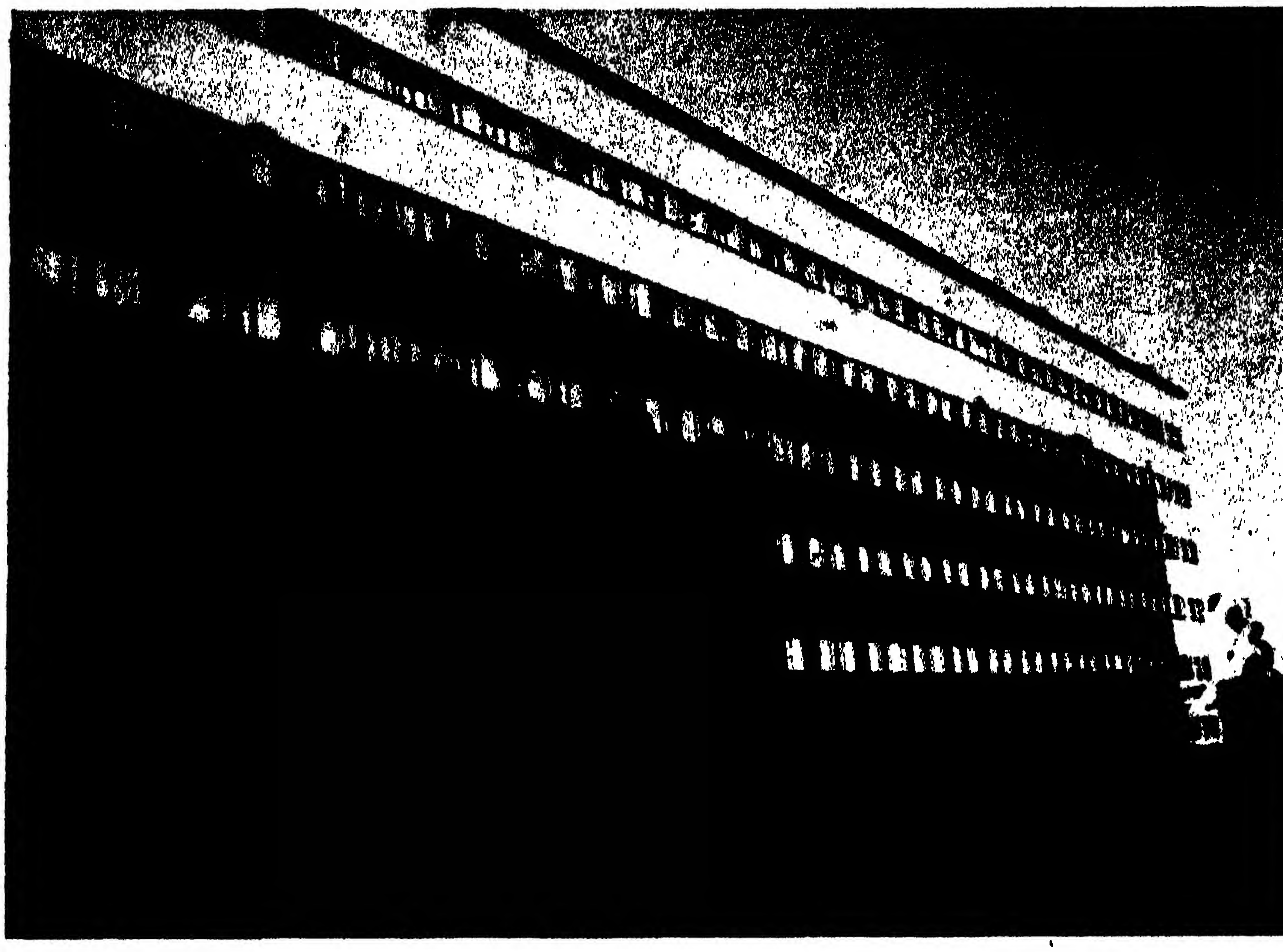
At this meeting, and at the smaller ones also, I found it difficult to determine just how seriously the older scientists of pre-revolutionary days regarded this outward form and expression of a spirit not unfamiliar in America among other classes of people. I was convinced, however, that in their every-day work the older scientists on the whole yield to none in being active and sincere proponents of the new system and philosophy of their régime; most are unquestionably leaders in the procession, if they are in it at all.

At the close of the meeting I sounded one of my friends, a younger professor of forty, as to what he thought of all the speechifying, and he confessed that ah, yes! the Russians *did* have a natural fondness for long speeches and plenty of them, even to liking to hear the same things over and over and over again. He recalled that during the preparations for the Physiological Congress he had attended committee meetings twice a week for six months before the event, but that beyond discussion nothing was done until three or four weeks beforehand. With good-natured appreciation, he freely cited other instances of the Russian preference to look upon the big ultimate problems of the future rather than to attack the immediate task on hand. As a Soviet doctor explained, when it was suggested to him that screens be provided for the doors and windows of a hospital filled with flies, they were not troubling about screens now, because when the time came, they planned to exterminate the flies both inside and out!

The capacity of Russians not to worry —not to "get in a stew"—gives them a quiet self-assurance which I learned to admire. As the English are traditionally calmer than the Americans, so the Russians seemed even calmer and quieter than the English. I found too, that, con-

SCIENTISTS ALL

(STANDING) A TARTAR, A CALIFORNIAN; (SEATED) A "UDARNIK," A COSSACK, AND A MUSCOVITE.



ONE OF A GROUP OF BUILDINGS HOUSING SIX THOUSAND STUDENTS IN NORTH MOSCOW.

trary to a casual opinion I had formed before my visits, they have a decided ability not only to laugh, but to laugh at themselves, with a characteristic childlike jollity. Everybody in the laboratory was amused when I read to them from a book in English which explained with some confidence that "when a Rusisan says 'right away' he means 'tomorrow,' and when he says 'tomorrow' he means 'never.'" Of their own accord, thereafter, they never failed to distinguish for me between an American to-morrow and a Russian to-morrow, in connection with things actually to be done or actually not to be done. From time to time I showed them pictures of my small daughter, selecting those which seemed to give her rather a Russian appearance, even though, in fact, she was not in the slightest of that blood. They, too, thought that she looked like a Russian baby, until one day some one happened to catch sight of some of the photos I had not exhibited, and exclaimed, "Why, he has been showing us all the ugly ones!" Once during a street-car jam at midnight, on the Nevsky Prospect in Leningrad, thirty trams in line were held up by an auto stalled in collision with the foremost one. An ambulance had departed with the injured within five minutes of the accident, but after a wait of more than forty-five minutes, I overheard one comrade in the crowd remark with gusto to another that evidently they were telegraphing to Stalin in Moscow to obtain permission to remove the auto from the tracks. This incident is suggestive of a prevailing Russian quip that the cure for bureaucracy is more bureaucracy.

IV

The day at the laboratory started at nine, when the udarniks (best workers) usually arrived, with others continuing

to put in appearance up until ten o'clock. Consistent with the planning element found in so much of Soviet life, a great deal of the routine work was mapped out on a day-to-day basis well in advance, usually by periods of three months. For instance, when I wanted some Kjeldahl analyses performed, the analyst would often look at her chart and announce a date already arranged for such work. (Dates instead of names of days are used universally, and in the Soviet weeks of six days, "rest-days" come on the sixth, twelfth, eighteenth, twenty-fourth and thirtieth of each month). In the higher positions, although the research worker has certain problems allotted to him in the general plan drawn up by the department for the year's work, and divided by the laboratory administration somewhat into quarterly quotas, there is in practice little undue interference with the execution of his work.

At two o'clock the main meal of the day is taken. Each institute commonly has its separate dining hall, and there is yet another reserved for the use of those of full professorial rank. At the latter the food was somewhat better, and more tastefully served. These main meals cost from one and a half to three rubles. In general, I found the food nutritious, and, although rather heavy in starches, not without variety according to European standards. Russians of all classes have notably a "carbohydrate" physique, tending to be short, stocky and solid. On each dining table was a plate piled high with slices of several kinds of bread, and my companions often remarked that I ought to eat more bread and drink less water. After lunch the bustle of the morning was not always regained, and frequently one came across huddles of a half dozen or more people deep in discussion of both work and, inevitably, personalities. At four, except in the event of a general meeting, or a language class, the workers would begin to leave. Overtime work was common, as in all scientific laboratories, but seldom regular save on the part of some of those housed at the institute, mainly bachelors. In the newer buildings, many of the scientific staff live in apartments in the institutes. Although this arrangement is not uncommon in European laboratories, the idea has been frequently put into practice in the U. S. S. R.

After a six- or seven-hour day at the laboratory, which is standard for most kinds of urban work, an average of one to

A GAME OF CHESS AT THE LABORATORY.

THE ACADEMICIAN-DIRECTOR OF THE LABORATORY (LEFT) DELIVERED THE FIRST SPEECH AT THE OPENING SESSION OF THE SUPREME SOVIET, JANUARY, 1938.

A GROUP OF LABORATORY WORKERS.

THE VISITOR FROM A FOREIGN LABORATORY IS SURPRISED AT THE LARGE NUMBER OF WOMEN SCIENTIFIC WORKERS.

three hours might be spent in some form of social endeavor. It is generally expected that every one, in his free time, will undertake some social service. This is an unwritten obligation and a matter of popular ethics. As in each factory or office, there is a committee at the academy to take charge of these activities and to adjust the distribution of various social tasks among the workers. Health, vacations, sports, theater tickets and language classes are among matters which receive this voluntary attention. It is quite common for older, more experienced workers to give instruction to those under them. During my stay at the laboratory one man was given the temporary, not unpleasant task of seeing that all went well with me. He was especially qualified to do this because, unknowingly, we had been fellow-students in early college days at Berkeley fifteen years before; he has now been permanently settled in the U. S. S. R. for ten years, with a Russian wife.

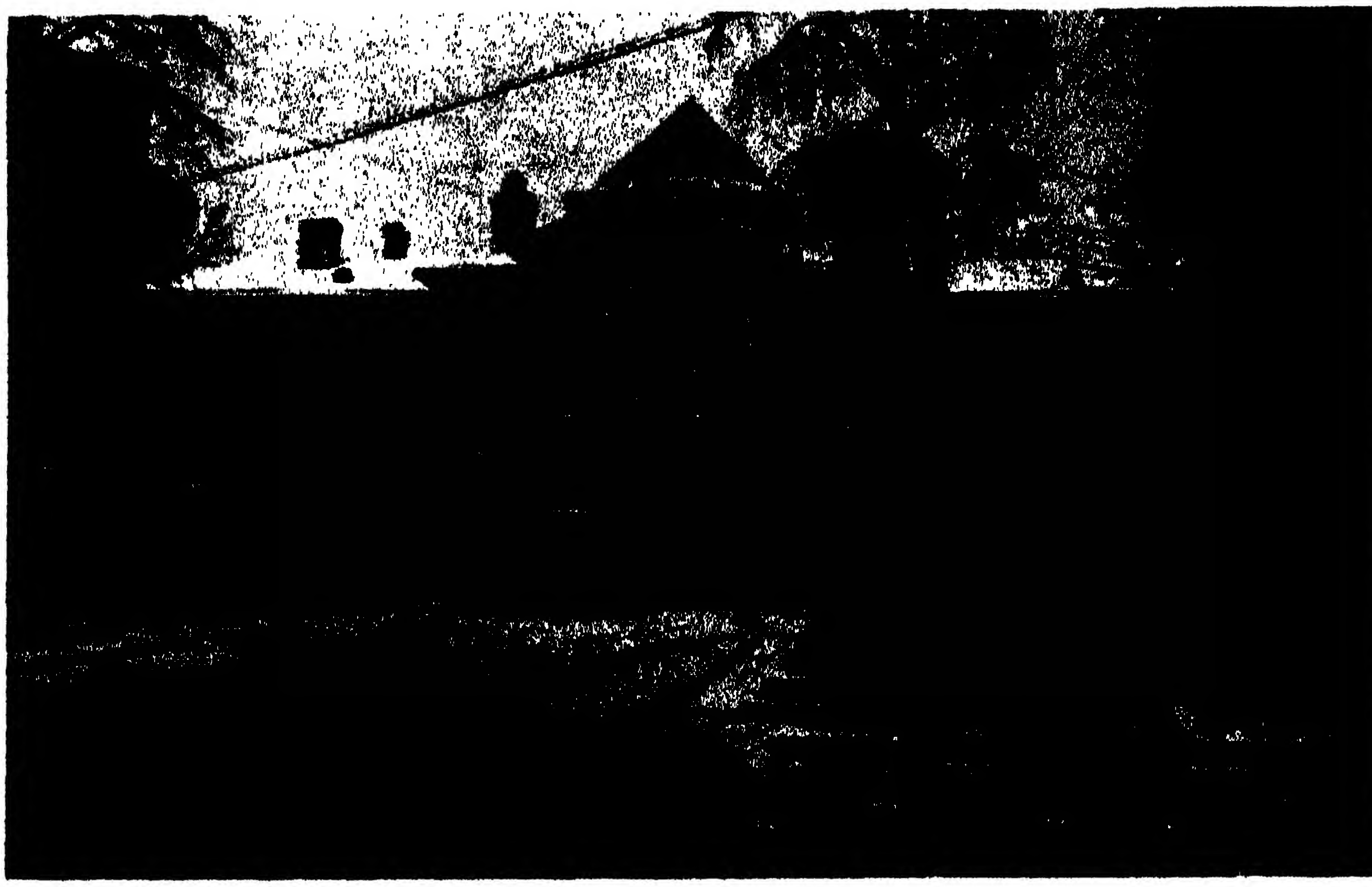
The chief social duty of the academicians and professors is to report and explain to other workers, both personally and through the press, concerning scientific progress and its relation to their work and lives. At five or six huge gatherings a year, held in the Palace of Culture, scientists of world renown, beloved and respected, tell of the developments of knowledge in their particular fields of activity to audiences composed mainly of factory workers—much as John Tyndall did in England in the nineteenth century during his long directorship of the Royal Institution.

The organization of foreign language classes is an essential feature of laboratory life. These classes are held after work at the institutes, and became especially popular after the Physiological Congress. During my stay I was invited

to take an active part in the English class. Much use was made of stories written in the eight hundred and fifty words of Ogden's "Basic English," and also of Mrs. Ivy Litvinov's widely distributed English grammar explained in the Basic Russian which she has created. We would start the lessons by asking and answering formal questions in English, and this would usually develop into an animated, if somewhat hesitant, conversation about life in Russia and in America. Once we discussed the November Seventh parade through the Red Square, and it developed that some of them had not marched. I told them of a remark that had been made to me about "only the babies and old ones left behind" and they volunteered, "Yes, and the lazy ones, too." We talked about the rôle of women in America—did many work in science?—did most ever do anything more than be stenographers or secretaries?—did they ever really run things? One girl, who admitted to their all being frankly envious of the mechanical level of civilization attained in America, said that she pitied American women, and spoke with pride of the absolute political and economic equality which she said was now established between men and women in the U. S. S. R. I replied, "Yes, but think of how many American women have homes of more than one room to live in," and was facetiously accused of being a fascist. I decided, from our various conversations, that most Russian scientists, even those generally well-informed, find it difficult to understand the nature of the opposition to the U. S. S. R. existing in other countries, or to grasp the idea of the "Red Scare" in the concrete and what it has meant in terms of circulation for foreign newspapers of another color. During my laboratory stay, I was asked many times by scientists, of all ranks, whether I had been "commissioned" to come to do my research—whether, in other words, I had, for some reason not readily evident to them, been "sent." It was a pleasure and reassuring to me to note first their interest in this point and second their immediate and invariable approval upon being told that the initiative had been entirely my own. Evi-

THE STUDY OF CONDITIONED REFLEXES

IN A HOSPITAL FOR (FOUR HUNDRED) PROBLEM CHILDREN, LENINGRAD. SALIVATION OCCURS ON ONE SIDE OF THE MOUTH ONLY, UPON INGESTION OF SUGARED CRANBERRY AND FLASHING OF PROPER LIGHT SIGNAL (BLUE LIGHT, LEFT SIDE, GIRL; RED LIGHT, RIGHT SIDE, BOY).



BIOCHEMICAL LABORATORY IN OLD PAVLOV INSTITUTE GROUNDS IN LENINGRAD.

dently something in the internal structure of their society and in the psychology resulting therefrom heightened the importance of, and gave special color to, this piece of information.

It is easy to find an opponent for a game of chess in Russia. Chess in Russia is to some extent what baseball and football are in America. Recreation rooms invariably have chess boards inlaid in the tables, and chess sets in store windows are almost as common as women's hats here. One morning at ten, after discussing experiments, the seventy-eight year old academician who directed our institute suggested a game of chess. He warned me that he had been playing for sixty-six years. We had three games, lasting for three hours, and of which he won two. We ended by congratulating each other upon the quality of our play. This interlude upon the part of a busy director, famed for classic experiments performed thirty to forty years ago, and now responsible for several institutes, was as pleasant as it was unexpected. On his visits to the laboratory, every other day or so, this academician-director shook hands with all personnel he met, from top to bottom in rank, and, in accordance with old Russian custom, only Christian names, first and second together, were used in mutual greetings and conversation. (I have no second name, but they had said, "that doesn't matter, what was your father's first name?" and upon being told, they replied, "Well, then you are Dean Fredericovitch, and your daughter is Diana Deanovna.") At the present moment of writing, the academician-director referred to has had the honor of delivering the first speech at the first session of the Supreme Soviet of the Union elected last month under the new constitution, and of presiding on the rostrum during the nomination and election of the president of this parliament. In addition to being a president of the Mendeleyev Chemical Society and chairman of the All-Union Association of workers in Science and Technics (Varnitso), he has been a member of the Moscow Soviet several times previously, a member of the Council of

the People's Commissariat of Heavy Industry, and a member of the All-Russian Central Executive Committee.

In England and America appreciation of the fine arts is high among scientists taken as a group, but the Russian scientists do not seem, contrary opinions expressed to me by some of them notwithstanding, to indulge to the same relative extent in the cultural life being built up around them; for one thing, they are too occupied with their more-than-average responsibilities. Their places in the concert halls, galleries and theaters are taken by the other worker types. Members of the Red Army are conspicuous at the very best theaters, where they receive preference of tickets and enjoy especially favorable rates. At the academy, nevertheless, there is an individual whose duty it is to obtain such seats as are desired by its workers. Like most institutions, it maintains a fund, rather large, for paying for various social activities, including part of the price of theater tickets, up to as much as 50 per cent. in the case of the least well-paid workers, and also, on the other hand, as a reward in the case of the very best workers; the theater always gets the full price, though the worker may seldom pay it, unless he deals with the box office directly, as he may if he wishes. I attended many performances. The audiences were mostly quiet, often tense and completely absorbed. Twelfth Night was presented as a roaring comedy. Less attention was given to the truly sad aspects of Malvolio than by the Stratford-on-Avon players, and much play to Maria, the clown, Sir Toby and Sir Andrew. The people in the audience, gripped throughout, leaned forward in their seats when, in the final scene, Sebastian ran in with sword in hand, clearing up all situations and difficulties, and, with the relaxing of the tension, cheered just like any cinema crowd when the hero finally arrives. "Pickwick Papers" was presented at the First Moscow Art Theater in eight long

HEADQUARTERS OF NEW PAVLOV INSTITUTE

OUTSIDE LENINGRAD (KOLTUSHI), CONTAINING A MAZE OF CONDITIONED-REFLEX CHAMBERS.

FOR SCIENCE TO PROSPECT. A FARM NEAR MOSCOW.

scenes which followed closely the original drawings of Phiz.

V

I estimated that the salary spread in the institute at the academy at which I worked, and in the larger Soviet universities generally, was probably slightly wider than in similar institutions in the United States. The salaries of scientists of some experience, men in their early thirties, and not including heads of laboratories, average in Moscow perhaps eight hundred roubles a month. It is not easy to estimate the standard of living as compared to American standards, but, in general, the eight hundred rouble salary would provide a three-room apartment, a part-time maid and a vacation in the Crimea every year or so. Workers with less experience, but with some previous training of a formal nature, receive from two hundred and fifty roubles a month upwards. Academicians, laboratory heads and professors of full rank commonly receive one to two thousand roubles a month, and are often provided with cars in addition to their salary, especially when their official duties require their presence in several institutions. Owing to the shortage of leaders, ranking scientists often hold two or three positions, directing and teaching. Many of them still work in both Leningrad and Moscow, commuting back and forth, on overnight trips, every few weeks during the academic season.

The average age of the scientific workers is quite low, about thirty, I should judge. The visitor from a foreign laboratory is surprised at the large proportion of women workers, about 30 to 40 per cent. In one well-known laboratory in Leningrad which I visited, eighty-one of the ninety-two workers happened to be women. The number of women directors of laboratories or sections is proportionately smaller, but without doubt greater than in Western countries. Of course, there has been an established tradition

of Russian women working outside the home, not only in the field, but also in a variety of intellectual pursuits, particularly in the social services and in politics, and this has been greatly extended under the new system.

As in the laboratories of other countries, some research workers are turning out work of high quality, many are not. It must be said for the present that a distinctly low critical standard is generally regarded to prevail in Soviet science taken as a whole. Naturally there are many individual laboratories where the highest standards exist, but these do not compensate for the others, though doubtless they merit the most attention. A series of related causes has contributed to this state of affairs: the shortage of first-class scientists for the training of personnel; the lack of up-to-date laboratory equipment; the necessary emphasis on results of more immediate application; and, perhaps most important of all, the isolation of the last twenty years, with the accompanying inadequate interchange of publications and criticism with other countries. It is worth remembering, too, that a large proportion of the lower ranks of scientific workers, as of the people on the street, are peasant in origin and outlook, and that decades will be required to alter and remove this background. The tempo of life in the U. S. S. R., increasing rapidly on a relative scale, is still geared on an absolute basis to about one third the level existing in the most advanced Western countries; the same slow tempo is known to have prevailed during the early stages of industrialism in England, Germany and other countries not much more than a century ago.

There is no lag, however, in the application of science to large-scale operation, and this often in a manner to cause envy among *confrères* in other countries. It is a factor of great importance in certain studies, especially in the sciences related to agriculture, where outstanding work has been carried on, particularly in genetics, in terms of square miles.

With the development of the light industries the problem of laboratory equip-

PHYSIOLOGISTS ON THE WAY TO LENINGRAD.

THE CAPTAIN (CENTER, CLOSELY-SHAVEN) OF A SOVIET BOAT PLYING FROM LONDON TELLS DELEGATES TO THE FIFTEENTH INTERNATIONAL PHYSIOLOGICAL CONGRESS WHAT TO EXPECT UPON ARRIVAL IN LENINGRAD.

THE KREMLIN, WITH NEW BRIDGE UNDER CONSTRUCTION

TO ACCOMMODATE SHIPS FROM THE VOLGA-MOSCOW CANAL. THE CONCLUDING BANQUET OF THE PHYSIOLOGICAL CONGRESS WAS HELD IN THE BUILDING AT EXTREME UPPER LEFT.

ment is being remedied. In the past the more important instruments had to be imported at almost prohibitive expense to the country.

The state of isolation is beginning to receive attention, both internally and abroad. At the Physiological Congress visiting delegates expressed hopes that the Soviet government would, in the near future, provide a considerable sum to give young scientific workers the opportunity to study in the laboratories of other countries. The first post-revolutionary scientific congress of note to be held in the Soviet Union did not occur until 1930, when the International Society of Soil Science met in Leningrad and Moscow, and followed this with an extended tour of the country. The Mendeleyev Chemical Congress met a few years later. The first big international congress was the Physiological Congress, inaugurated by Pavlov in the palace of the old Duma, and attended by some twelve hundred foreign scientists. It opened the eyes of the Russians and Russian scientists to the necessity of their keeping in touch with the outside world. Unfortunately, other trends within the country have for the time being prevented much accomplishment here. The scheduled International Genetics Congress was cancelled somewhat over a year ago; on the other hand, however, the International Geological Congress met in Russia last summer under auspices nearly as favorable, if not as elaborate, as those of the Physiological Congress.

VI

In weighing the achievements of Soviet Russia and evaluating its scientific life, it is more profitable and interesting to compare new and old Russia, rather than new Russia and modern America, and it is important to do so on a humanistic as well as materialistic basis. I was told many times, literally and in substance, "You Americans and English are busi-

ness people. We enjoy life." The thick throngs leisurely promenading the Nevsky Prospect, the Red Square and other similar thoroughfares every summer and fall evening from six until far past midnight are a memorable sight.

On November Seventh, the anniversary of the revolution, one thousand academy workers, including academicians and professors of three score years and more, march with a million and a half of the populace in the parade through the Red Square. At such a time one of them said to me, "You will never see anything like it." The academy group met at its headquarters some three miles away, walked briskly for the first two miles, and then was forced to slow up upon approaching the Kremlin, as processions from a dozen or more routes converged at the entrance. The sea of banners suggested some medieval pageant. Now and then during the march small impromptu groups of children and young people, in fancy dress and often singing and dancing, cut across the line on some route of their own inclination. One such group of small boys sang lustily the popular march from the Soviet film, "Jolly Fellows," with most, but not all, of its sharps and flats. "Would Stalin still be there?" was the question every one was asking as time for entering the Square drew near. If not, would Kaganovitch, Molotov or Voroshilov? Yes, at two o'clock, after four hours of parade, and three more yet to come, all four leaders were still there, gayly waving back from the reviewing stand in reply to the cheers of the marchers moving past, one hundred abreast in ten files of ten persons each.

That night, after the parade, the illuminated red flag waving ever so slowly over the Kremlin in the cold crisp winter air, without visible means of support, looked very small but very firm at its great height. It seemed as imperturbable, in its one sixth of the globe, as the four lions of Trafalgar Square in an even greater empire.

It is necessary to enter with some sympathy into this Russian atmosphere, with its interesting past, its present humming and a future ever in the air, to realize even the obvious features of a society based so distinctly upon a scientific philosophy—a society wherein it is so generally believed that the more science develops, and is allowed to develop, the better off every one will be. With a consciousness that his knowledge will spread for the good of all, the Soviet scientist adopts a strong feeling of social responsibility, a frankly political outlook and a tendency more and more to collective living, working and playing in a country where, to quote the late Academician Karpinsky, "science is given a place of honor."

RECEDING HORIZONS

By Professor HEBER D. CURTIS
DIRECTOR OF THE OBSERVATORY, UNIVERSITY OF MICHIGAN

In his well-known poem "Ulysses" Tennyson makes that self-analytic Grecian wanderer say:

I am a part of all that I have met;
Yet all experience is an arch wherethro'
Gleams that untravell'd world, whose margin fades
For ever and for ever when I move.
. . . .
And this gray spirit yearning in desire
To follow knowledge like a sinking star
Beyond the utmost bound of human thought.

The thought thus beautifully expressed was by no means new in Tennyson's day. Philosophers, thinkers, religious believers, even the man in the street of ancient or more modern times, have all given an awed adherence to the thesis that the ultimate in knowledge is unattainable—that, however so many the new data of the universe that may be found by man, there always will be revealed other facts beyond, and a new, wonderful and apparently mysterious and unreachable horizon will be glimpsed in the distance to take the place of the horizon that has just been attained.

It was an Englishman who expressed this thought in a somewhat more concrete form when he said, "Any good theory brings in more problems than it removes." That our body of observational knowledge can never reach an end in some final and ultimate horizon is a truism that seems generally admitted. Though the illustration may seem somewhat far-fetched, the increases in data secured by man through the ages may be somewhat fancifully compared to that mathematical curve known as the rectangular hyperbola, one of whose characteristics is that it will never touch the two straight lines to which it is referred, though it will asymptotically come infinitely close to such a contact after the lapse of unlimited time.

It is a rather comfortable and satisfying curve of progress, to minds that are pleased with such speculations. For if we consider the conditions of its approach to one of its rectangular axes, we may argue that additions to knowledge will gradually become relatively smaller and smaller as we gradually approach to, but never reach, the line that represents complete and final knowledge. But the curve may equally well be reversed for the benefit of those who wish to dream their dreams in accordance with the assumption that man's progress was at first almost infinitely slow; then we may postulate that future additions, future discoveries and future intellectual progress will become almost infinite in the magnitude of the individual Brobdingnagian strides we shall be making, even though our progress to the line representing the absolute will be as infinite in duration as it was from the former view-point.

Many will feel that the last-mentioned point of observation for such holiday dreams appears to be more accordant with our own evaluation of the advances recently made in pure and applied science. But the view-point depends entirely upon whether we appraise the utilization of fire and the invention of the first bow and arrow as relatively more or less important in man's upward climb than is radio and gasoline. It is perhaps not generally recognized that such beliefs in the limitations set upon our knowledge of the eternal verities involve one or both of two equally interesting assumptions and that astronomy is rapidly furnishing us with certain data that may some day make it possible for man to choose somewhat more certainly between these assumptions than is at present possible.

The first of these assumptions presupposes a body of facts in the universe that

we may characterize as essentially unknowable; transcendent in the usual sense of that word, though in no way transcendental in the Kantian nomenclature. This science is assumed to be unknowable as such, not because we may never have the instruments and the opportunity to study it, but intrinsically and because of the natural limitations of the human mind.

The second assumption places no final limit on man's mind or reasoning powers. It maintains that there is nothing accessible in the universe that we shall not eventually understand, granted only that is perceptual to our senses and to our adjuvant instruments of measurement; though our mentalities may be imperfect to-day, this assumption postulates they will eventually be adequate for any problem which the picture or model of the universe may present. There will then ultimately be no physical fact that is transcendent, mysterious or unknowable merely because of any supposed limitations of our intellects. But, as on the first assumption, our knowledge can only asymptotically approach the absolute, and never reach it, merely because the universe itself possesses the attributes of infinity—perhaps even *im kleinen,* and more certainly in the large, in so far as considerations of mass, extent and duration are involved. To whichever of these two assumptions we may adhere for the present as a working basis, it will be evident that we shall eventually come out of the same exit door for either.

Vast aggregations of physical and purely astronomical data may be assembled and so treated as to support either one of the two basal assumptions just outlined. For example, the phenomena of light, electricity, matter, gravitation, the molecule and the atom, the neutron, electron and positron, exhibit fields where even to-day we have a vast power of control and a rigid codification of processes, though our factual knowledge of the actual entities involved remains almost precisely zero. This condition may be taken as a support for the first assumption mentioned. Many thinkers have, for example, seriously suggested that the basal and ultimate nature of matter and radiation is something that we may have to admit is intrinsically unknowable. We recall here how Eddington has somewhat whimsically characterized the atom —"Something unknown is doing we don't know what."

We shall have to admit at this point that such an assumption of an unknowable sub-stratum may be only a short-sighted and rather naïve escape from our difficulties, open to many objections. The opponent may say with good reason that the entire history of scientific thought is one where the formerly mysterious fact has been made understandable. Is not such an assumption, such an objector will say, really a result of the same naïve reasoning as that employed by primitive man, who placed a much larger body of phenomena in the reign of the unknowable—explaining lightning, thunder, day and night, the sun, moon and stars as under the control of unknowable spirits, of good and evil genii? Primitive man made such assumptions and was entirely logical in so doing, according to his lights. He was really as scientifically minded as Eddington when he summarily dismisses the atom as beyond the pale, or as de Sitter was when he accepted a mysteriously expanding universe. For whatever objections we may voice as to the validity of the simple explanations advanced by the savage, we are to-day basally not very much more logical and scientific than he, since science consists only in observing things and then formulating the simplest possible theory to explain these things. Both Poincaré and Jeffreys have maintained with some reason that the theory that has the best *a priori* probability of being true is the theory that is simplest.

Perhaps the very simplicity and naïvete of this first assumption may prove

to be its eventual undoing. So rapidly has recent scientific progress pushed farther away from us the horizons beyond which these seeming unknowables lie, that many prefer to put aside all speculations as to a possibly transcendent physics as non-contributory and profitless and to adopt, with good reason, a waiting policy, confident that the scientific future will take care of itself and reasonably sure of the thesis that our present horizons are apparent only, certain to vanish and be replaced by new ones as they did for that ancient seafarer, Ulysses.

It is, however, of the other horn of the dilemma that I wish to treat, namely, the thought, speculation, holiday dream or whatever the critic may prefer to term it, that our horizons are receding merely because of the fact that we have to do with a universe that is infinite in both space and time. It assumes that no datum of the universe is transcendent or intrinsically unknowable; it makes the further less warrantable assumption that man's intellect will eventually asymptotically approach to an infinite knowledge.

For this phase of the discussion we shall turn to astronomy and the modern evidence of the infinitely great, and pass over the at present equally transcendent mysteries of the infinitely small—the wonder of the atom, the mysteries of radiation, the complexity of the proteins and that strange horizon, seemingly coming closer to us at present, where we appear to pass from dead matter to the virus, enzymes, bacteria and life.

I regard it as perhaps the most significant contribution ever made to philosophical thought that the astronomical development of the past two decades has given us for serious consideration eleven separate and distinct theories of an infinite universe. One such theory, it would appear, would have been sufficiently wonderful and startling, and would have formed a suitable text for mighty volumes. Of these eleven sorts of an infinite universe, two are Newtonian, that is to say, they involve only the evidence of our senses in the ordinary connotation of that phrase and are based upon the three dimensions of classical physics. The other nine types replace two earlier types that had been shown to be erroneous; they are based upon the theory of relativity and involve transperceptual relations; there are nine of them according as we assume a certain exceedingly minute and still unknown cosmical constant to be positive, negative or zero, and according to our choice of the curvature of space as positive, negative or flat. As a matter of fact, these nine types boil down to two—a universe that is actually expanding or a universe that is oscillating, that is to say, alternately expanding and contracting.

It should be pointed out at this juncture that this very recent contribution of astronomy to philosophical thought has essential differences from the concept of infinity debated by philosophers of all time. Their assumption of infinity was academic, abstract and detached; astronomy gives us a concept that is in a sense more concrete; though admittedly unattainable and unrealizable as a concept, it at least marshals some very interesting evidence and weighty mathematical analysis in its support.

One further repetition of this caution seems advisable; astronomy can certainly advance no claim to a proof or disproof of infinity in the abstract; it realizes, fully as well as philosophy, that the full knowledge of any infinite concept is beyond the finite brain of man. But astronomy may, with propriety, assert that it has, perhaps for the first time in the history of human thought, adduced certain lines of observational evidence that make some postulation of a spatial infinity at least more probable to the physical scientist.

The objection may be raised at this point that the astronomer has no right to take part in speculations whose basal character has been recognized to partake

of the insoluble in the theory of knowledge. The astronomer, says the philosopher, has neither the obligation nor the proper qualifications to make his speculations in such abstruse fields worth while, from the philosopher's standpoint. But the astronomer has become somewhat restive and refuses to be bound longer by such restrictions and prohibitions. He has defined a philosopher, somewhat ungraciously, as an individual who claims for his own and arrogates to himself all the really interesting parts of all other sciences. Though willing to admit the all-embracing character of the field of philosophy, the astronomer is to-day demanding the right to do a moderate amount of speculation of his own, even though, philosophically speaking, he may may be as a bull in a china shop. Furthermore, the physicist and the astronomer are to-day the ones who seem to be furnishing not only the puzzles, but the lion's share of the clues that may eventually clear up the puzzles in part, and the astronomer, in particular, now feels that he has earned the right to quote to the philosopher in his own defence that ancient prohibition, "Thou shalt not muzzle the ox that treadeth out the corn."

In presenting some of this evidence, I shall try to refrain from confusing the issue by citing too much of the incomprehensible numerical data of modern astronomy, though a little of this must be given here and there. For, not even if we took the wildest financial dreams of present-day politicians and translated these into Portuguese milreis or Chinese cash could we hope to equal or be able to understand our astronomical distances.

The evidence from which proceed our eleven modern theories of an infinite universe is rather simple in its outlines and in its essential characteristics. Put very briefly, our own sun is only one of several billion suns that are assembled in a great reading-glass shaped space, and this vast congeries of stars we call a Milky Way or a galaxy. Scattered throughout all the accessible space exterior to this Milky Way of ours, at distances apart that average a million light-years or more, are several hundred million other Milky Ways, each one made up of billions of suns, as is our own. These brother Milky Ways range in apparent size from large and wonderful spiral structures that are the most beautiful things in the heavens, down through successively smaller sizes, due to increasing distance from us, till finally we see them as mere flecks on the photographic plate in the most powerful telescopes that we possess. These minute specks, so small and uninteresting, nevertheless possess a great fascination for the thinking mind, for each of them possesses its billion suns, like our own galaxy, or the larger spirals relatively near to us. Actually of the same order of size as our own Milky Way, they look so small merely because they are so far away. I have, and I feel conservatively, estimated their probable distance as a billion light-years, where each light-year equals six trillion miles, or a total distance in miles that requires twenty-two figures for its expression. A Milky Way in a flyspeck!

A very considerable number of abstruse papers have been published, devoted to the manner of arrangement in space that obtains for these millions of brother Milky Ways. These studies are complicated by many factors into which I can not here go in detail—assumptions as to the possible absorption of light in space, a shifting of the total light to the red through either velocity or great distance, etc. Suffice it to say, by way of summation, that the consensus of present-day opinion maintains that these external galaxies are fairly uniformly distributed in exterior space. That is to say, their distribution possesses the factor of continuity, in the philosophical sense; as we reach farther and farther from our own part of space we do not find that the number of galaxies in a given volume is becoming smaller and that the

effective density of space is becoming less. We confidently expect the new 200-inch telescope to show us merely eight times as much of the same distribution of the same sort of things in space. It is equally remarkable that we get no strange, new and aberrant forms of Milky Ways as we go outward; the continuity in the factor of structural form and the essential simplicity of the external universe are salient facts at which I never cease to marvel.

There is, then, a remarkable uniformity in the distribution factor, as well as in the forms assumed, and space appears to be populated with Milky Ways with a density that is uniform to the greatest distances to which our telescopes reach. We have no present cause for suspecting a change in this function of density; while we can not prove, of course, that space goes on indefinitely with this same distribution, our present evidence makes such an assumption not unreasonable. To repeat, observational evidence, which is all we have as a present guide, shows nothing against an assumption of an infinite universe, and a certain amount of indirect evidence in favor of it.

Such considerations as these, though much less certainly established in 1921 than they are to-day, prompted the great Swedish astronomer Charlier to publish at that date an epoch-making paper entitled "How an Infinite World Can Be Built Up." He used no transcendent four-dimensional space for his basis, but only the three dimensions of our experience and Newtonian physics. He showed that if things outside are arranged in systems, that is, suns arranged in Milky Ways, Milky Ways in clusters, clusters of galaxies in super-galaxies, and so on, the universe could mathematically go on forever, world without end, without running into any paradoxical difficulties. And the strange and interesting thing is that this universe of Charlier's, which I regard as perhaps the most probable of the eleven infinite sorts now available, seems to parallel the observed external universe with astonishing fidelity; things "outside" do seem to be arranged in this way.

But another interesting and still somewhat mysterious factor began to enter into the field of analysis at about the time of the publication of Charlier's memoir. Without going too much into minutiae of detail, the researches upon these external galaxies made during the past twenty years have brought to light an astonishing and overwhelming fact, not yet explained in a manner to win universal acceptance. Each and every brother Milky Way, with exceptions too few to note, seems to be receding from our part of space. The speeds of apparent recession are very high; the great majority are more than four thousand times the velocity of a rifle bullet and in one case at least amount to 26,000 miles per second, or nearly one seventh the velocity of light. And recall that these velocities, once more, are not at random, with some approaching and some receding, but all are receding from us, or at least seeming to recede. Note in addition that the farther away a brother galaxy may be from us, as shown by its apparent size, the faster it is receding from us. The relation, so far as our observations go, is then a linear one, varying directly with the distance or, what is the same thing, with the time of light travel. For every million years the light-ray has been on its way toward us, that is, for every six quintillion miles of distance (6 followed by eighteen ciphers), we find that there is an increase of about 100 miles per second in the apparent speed of recession. A small library of intensely abstruse treatises has been written in the attempt to fit this astonishing and apparently universal characteristic of other Milky Ways into the coherent scheme of things. How shall we explain it, asks the astronomer?

I have mentioned the existing choice presented in several branches of science between theories based on the perceptual

on the one hand, and on the transcendent on the other. No more interesting example of this dilemma as an illustration of a present and pressing need in our physical sciences could have, so to speak, been made to order than the history of the attempts to explain this recession of other Milky Ways. Shall we then attempt to explain these peculiarities of our external universe as in every way conforming to what we sometimes loosely term the evidence of experience, that is to say, as given by our senses in the usual connotation of that term? Or shall we, on the other hand, call in to our aid the transcendent, the mysterious, the trans-perceptual?

It is either fortunate or unfortunate, depending upon the individual point of view, that a body of transcendent physical theory was already at hand and available a decade before the peculiar fact of the recession of other Milky Ways was firmly established by observation. I am fully aware that any ardent believers in the theory of relativity who may read these words will object strenuously to my characterization of the Einstein theory as in any way transcendent, yet I feel that this is not an overstatement. The so-called Newtonian universe of Charlier and what we now term classical physics was definitely based upon the three dimensions of experience with that still somewhat mysterious phenomenon known as time as a separate entity. The mathematics of relativity is essentially four-dimensional, and time and space do not in this theory possess an independent existence, but are united in a single space-time relation. The relativistic fundamentalist regards this union of time and space as a very beautiful contribution to logical thought, and does not hesitate to evaluate it as a contribution far superior to any made by Newton.

Those who to-day do not accept the theory of relativity as inevitable are very definitely in the minority—that must be admitted. But there is still a fairly weighty minority of scientists who are unwilling to admit that the concept of contiguity in a space dimension is inseparably and indissolubly bound up, in the fundamental nature of things, with the concept of consecutiveness in a time dimension, however these two concepts may be fused in the recorded observations. We listen to the puzzling dissertations on the peculiarities of imaginary clocks on moving systems, with intercommunicating signals sent with the fundamental velocity of light, and while admitting that light coming from enormous distances, brings to us living energy of the remote past but in the present tense, are still unconvinced and feel that this has no vital connection with *das Ding an sich*—the actual structure of the external universe.

These words of doubt should not in any way be taken as a dictum on my part that relativity may not be true; such a statement would not only be foolish, but may well prove eventually to be false. The late G. K. Chesterton put into the mouth of Father Brown, that interesting philosophical priest of his creation, the words, "Ten false philosophies will fit the universe"; it is indeed possible that the Newtonian universe of our sense perceptions may turn out to be one of the false ten, while a trans-perceptual universe may be accepted. For it is in no way the purpose of this discussion to enter the lists for or against the theory of relativity, as such. It is rather to emphasize and draw to your attention the strange forks in the road at which astronomy to-day finds itself, and one fork leads to the Einstein theory. To repeat—we have before us a certain dilemma of choice, and never before in the history of physical theory has the choice been put before us so definitely, with one fork of the road leading to a Newtonian universe perceptual by our experience, and the other fork taking a course that leads to some type of relativity universe that may perhaps be described, so long as our brains function

in their present mold, as transcendent and trans-perceptual.

The history of the attempts to describe the universe as four-dimensional in the relativity sense and in particular to explain thereby the apparent recession from us of all other Milky Ways as a necessary consequence of the introduction of a combined time-space coordinate, has exhibited interesting changes.

By 1917 both Einstein and de Sitter had postulated closely allied forms of a four-dimensional universe; in Einstein's form the space-time element was quasi-cylindrical, in de Sitter's it was quasi-spherical; in so far as the mathematical treatment was involved. In these two earlier relativity universes the recession of other parts of the universe was apparent only; that is, it was part of the fundamental basis of things that distant objects should *seem* to be moving away from us, but no actual physical expansion was involved.

These two universes held sway till about 1929, when almost simultaneously a brilliant young American, Tolman, and a very able Belgian priest, the Abbe Lemaître, proved that the universes of Einstein and de Sitter were unstable, because of their static construction, and hence could not exist. Both Einstein and de Sitter accepted these conclusions, and there gradually arose a new body of theory which may be described, very roughly, as a kinetic relativity universe, in which the observed recessions of other galaxies are *real;* the acceptance of this modern form of the theory means, of course, that the universe is actually expanding at a high rate of speed, and the farther we move from our part of space, the greater is the rate of expansion. McRae and McVittie, a little later, maintained that such a universe must necessarily contract; inasmuch as these two investigators are Scotch, as indicated by the two first letters of each of their names, some thus found an element of humor in a subject otherwise unutterably dry. This interesting conclusion has since been withdrawn, however.

De Sitter later showed that nine types arose, depending on the initial assumptions mentioned earlier, which effectively reduced to two sorts, expanding or oscillating, nor can any available evidence decide which assumption is the more correct. No important alteration in this theory has been made during the past few years, though papers continue to appear on certain aspects of the analysis.

We find to-day among the adherents of the theory of relativity all shades of opinion as to the reality of the theory of an actually expanding universe. Some relativists accept the theory in a somewhat cautious and guarded fashion—as an interesting possibility, not yet fully proven. A smaller number, among whom we may mention that very able, definitely mystical and apparently somewhat credulous Quaker, Eddington, have championed the expansion theory with an unbounded enthusiasm. Eddington is even ready to assume that two billion years ago all the hundreds of millions of other Milky Ways that we can detect with our powerful reflectors were concentrated within the relatively small volume of a single Milky Way, or in some sort of giant primordial molecule, the germ from which all the physical creation has sprung. To the objection that two billion years is not a very long time, geologically and biologically speaking, Eddington has said that we must shorten these vital and apparently firmly established time-scales. Small wonder that one able reviewer has expressed in print his wonder whether Eddington himself really believes all such bizarre conclusions! We thus find to-day two schools of thought among the only true believers, for so they regard themselves. One school follows Eddington in taking literally the observed facts as to the recession of the external galaxies and demands the so-called short time-scale for the process, the word "short" being used in its astro-

nomical or geological sense as a quantity of the order of one or two billion years from the very start till the present. The other school accepts an expanding universe, but seeks evidence or qualifying facts that will permit the use of the long time-scale, which grants to the astronomer a time of expansion perhaps a million times longer, and probably sufficient for the life period of the component stars that form our Milky Ways, for the formation of our solar system and for the age-long processes of geology and biology. No school has as yet arisen as a champion of the theory of an oscillating universe, perhaps simply for the reason that no evidence whatever can be found that bears on such a possibility.

A Newtonian infinite universe will, of course, have no horizon other than the horizon that marks the limit of present or future telescopic power. The various possible types of relativity universe have, however, an actual horizon of a very curious sort, referred to with some frequency in papers in this field, even though it is probably little more than a mathematical figment. This relativity horizon is as unattainable in reality as the utmost bounds of a Newtonian infinite universe in that neither our telescopes nor the light-ray can ever actually reach to it. But it is a horizon at which the universe ends; within it exists all the matter, space, time and energy of the great whole, and beyond this peculiar horizon there exists neither matter nor space nor time.

So much then for the fork of the road that leads to the mystical, the transcendent, the trans-perceptual; many wish to travel by this fork. But there are not a few who still prefer to choose the other fork of the road, that leads to an infinite universe in the Newtonian sense, and to retain for the framework of the universe only the three dimensions of ordinary perception.

Those who desire to travel by this second fork are now asking themselves the question—is there some other way by which the apparent recession of the galaxies and the apparent expansion of the universe may be explained by a mechanism that is "reasonable," if we define "reasonable" in a very narrow sense as a function requiring no phenomena that are transcendent or contrary to what we assume are the three-dimensional limitations of our perceptions of space? The answer is that such an explanation has been suggested and is perhaps in sight, though as yet on no firm mathematical basis. I shall use "reasonable" and "unreasonable" in this very special and narrow sense, a use open to attack on a number of philosophical counts.

For in the very limited sense thus defined, it must be admitted that the concept of an actually expanding universe is "unreasonable." That a few hundred million Milky Ways, at an average distance apart of one million light-years, and spread with considerable uniformity throughout a spherical space whose diameter is a billion light-years or more, should possess some mysterious interconnection or repulsive power that drives them all away from an equally mysterious center at speeds that are an appreciable fraction of the velocity of light, certainly seems "unreasonable." It seems diametrically at variance with every known fact of present-day celestial mechanics. It can not, furthermore, be regarded as a simple theory, nor can we easily imagine a cause for this uniform motion outwards that is inherent in the nature of things, that springs inevitably from the arrangement of the matter in the universe itself.

Prophecies are easy to make, but almost uniformly wrong. So "unreasonable" does the theory of an expanding universe seem to me, however, that I venture on a prophecy, with a full realization of its possible ultimate incorrectness. It is my measured belief that a century from now the physicist and the astronomer will look back upon this theory of 1938 with a

somewhat tolerant smile and that he will mentally classify it along with the chemical theory of phlogiston or the pre-evolutionary tenet that fossils were created as such, *in situ*, with no previous vital activity in a living animal. This prophecy applies only to a certain result that has been adduced from the theory of relativity, not to the theory itself. For all I know, they may possibly be teaching the theory of relativity in the grammar school one hundred years from now, though I strongly doubt it.

We must then search for some alternative and apparently "reasonable" theory, if indeed such exists, in the light-ray itself. If something happens to the light-ray in its passage through quadrillions of miles of space that can shift the lines of the spectrum to the red we shall still have the measured speeds of recession that we at present observe in distant Milky Ways, but this recession will be only *apparent* and not *real*, and our universe will not be expanding. We shall be just as logical in such a course as was the relativity theory of 1920 which, as stated earlier, postulated that the expansion of the universe was apparent only. Our possible explanation, however, will require no excursion into the limbo of a fourth dimension, nor will it require a formulation of the framework of the universe in 16 equations, each with 16 terms, or 256 terms in all.

Such an explanation, which seems not "unreasonable" *a priori*, will then seek for the cause in the equations of light, and a relatively simple physical fact will take the place of a transcendent framework. It must be admitted at this point that we do not as yet have the mathematical and physical proof for such a behavior of light, but a number of theorists are being attracted to the possibility of such an explanation. It must be admitted, also, that some of these attempts, based upon the quantum theory of light, seem to lead to a cul-de-sac, so that some investigators have stated it to be impossible. It requires, to put it simply, that something must happen to the light-ray to cause the vibrations of the light to be slowed up a very little, so that the crests between the waves are farther apart. It is as though the vibrational aspect of light becomes a little tired in its passage through the tremendous reaches of space. Such an explanation would apparently leave untouched, however, the velocity of light itself in free space. The ratio by which the vibrations become slower and the light waves a little longer is exceedingly minute, it may be added. To fit the observed facts this factor of expansion needs to be only one quarter of a quintillionth, or a fraction whose numerator is unity and whose denominator contains 18 digits. Let no one object at this point that we do not know the nature of radiation, nor what the light ray is, nor whether its waves have crests. That is admitted, for science must perforce be concerned first with phenomena, and only later, if possible at all, with the basal entities that seem so far beyond our receding horizons.

I feel that such a solution of our dilemma will ultimately be found and that we may then proceed on that fork of the road that presupposes a three-dimensional universe. This article must remain as far as possible untechnical, though it touches fields on the borders of present-day analysis. It is worthy of mention, however, that Maxwell's fundamental electromagnetic equations, which are partial differential equations of the second order, contain in their derivation by that great master, a term that is the sum of three first order derivatives. Maxwell pointed out that this term would be either zero, a constant or linear with the time, and hence could not affect the wave motion proper, so he discarded this term in his solution. As a matter of fact, he apparently had to do this to get a convenient solution. But it is at least possible that the solution of our expanding

universe difficulties may lie in this discarded portion, for as this may be linear with the time, it could permit some relation that would increase with the distance traversed by light. It should be once more emphasized, however, that the proper solution permitting this has not yet been rigorously formulated.

So much, then, for the interesting dilemma that present-day astronomy offers the philosopher. Whether we shall eventually be content with a three-dimensional perceptual universe and find the cause of our difficulties removed by adopting some new analysis of the light equation based on classical physics, or whether we shall continue to follow the present trend and seek to find a solution in a universe that is four-dimensional and in a sense trans-perceptual, still rests on the knees of gods. Certainly, in either event, our horizon will continue to fade forever and forever as we move.

Nothing, in fact, is more startling than the way our horizons have receded since the beginning of this century. In 1900 we talked with great hesitation and uncertainty of distances as great as five thousand years of light travel; now we with far less uncertainty speak of distances of a billion light-years; we have caused our horizon to recede ten thousand-fold during the past three decades. The proposed 200-inch telescope will theoretically push the accessible horizon twice as far away as now observed and make it twenty thousand-fold as distant as it was a quarter of a century ago. We expect with this great instrument to do a great many things much more quickly, but the conservative astronomer, unmoved by the clamors of the press for something really interesting, knows that we shall simply reach twice as far and study a volume of space eight times as great as that now accessible, and that we shall find in this added volume just eight times more of the same sort of universe we now have.

This, of course, is not enough, though we can at present envisage no new instruments that can place our actual observational horizon farther away. But we can always go on from what we have by invoking the apparently universal principle of continuity that obtains in the world outside and beyond these receding horizons. With the tools of mathematical analysis we can extrapolate, a rather dangerous process in many lines of physical research, but one that has thus far shown no weakness when applied to the external universe. On the wings of the intellect we can fly far beyond our receding horizons and the astronomer to-day demands as his right the privilege of speculation on the existence and arrangement of an infinite universe, infinite in both space and time, with all the interesting conclusions that may follow such a speculation, surely the most daring step that mere physical observation has ever permitted us to make.

We still are uncertain whether we may have to bring in the transcendent and unknowable in such speculations, or whether our infinite universe includes only the physical facts that are knowable with our finite brains and measurable with our gross measuring instruments of science. But we are happy in the realization that our astronomical horizons are receding ones; that apparently we shall have the joy and pleasure of achievement for all time to come in pushing farther and farther from us the limits of that untraveled world whose margin fades forever and forever as we move.

SURGICAL MAGGOTS IN MODERN MEDICINE

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Introduction

Many thousands of lives were taken during the world war, but just as many thousands of lives have since been saved because of the scientific achievements which resulted from it. One of the outstanding achievements is the utilization of maggots in the treatment of the bone infection known as chronic osteomyelitis. This disease is difficult to cure, often lasting years and causing a great deal of suffering. It is caused by pus-forming bacteria, such as the streptococci and the staphylococci, which make their way into the body through abrasions of the skin or through injuries from fractures, burns, deep cuts, gunshot wounds or explosions. The disease can also develop from some other infection of the body, such as an abscess, in which instance the organisms are conveyed to the bone by the blood stream. Although the maggot treatment was at first confined to osteomyelitis, experience has shown that it is just as effective in many other forms of disease known generally as "suppurative infections." Its applicability has extended even to the field of dentistry, where successful treatment of osteomyelitis of the mandible has been reported.[1]

Historical

The observation that maggots are of aid in curing disease can be traced as far back as 1557 when Ambroise Paré, the famous French surgeon, called attention to the beneficial effects of maggots in suppurative wounds. In 1799 D. J. Larrey, the celebrated military surgeon of Napoleon's armies, observed the curative properties of live fly-maggots in the extensively infected wounds of soldiers. J. F. Zacharias, a surgeon in the Confederate Army, was perhaps the first person who intentionally employed maggots in wounds. At the beginning of the twentieth century Larkin, a Chicago surgeon, used maggots in the treatment of osteomyelitis and chronic septic infections, and reported favorable results. But in spite of the fact that beneficial effects of maggots have been noted time and time again, the late Dr. William S. Baer,[2] of the Johns Hopkins University, was the first surgeon to put this age-old remedy into use on a scientific basis and to employ it in civil surgery.

Baer's Observations and Early Research

The initial impetus for Dr. Baer's subsequent work was an observation he made while he was serving with the American Expeditionary Forces on the battlefields of France. After a battle in 1917 two soldiers with compound fractures of the femur and large flesh wounds of the abdomen and scrotum were brought into the hospital. Although these soldiers had lain on the battlefield for seven days without water or food and had been exposed to the weather and insects of that region, they had no fever and there was no evidence of septicemia. Except for their starvation and thirst, they were in remarkably good condition. This unusual circumstance, in view of the extent of their wounds, and particularly in view of the fact that the mortality of compound fractures of the femur was about 75 to 80 per cent., even when the wounded had the best medical and surgical care that

[1] N. C. Ochsenhirt and M. A. Komara, *Jour. Dent. Research*, 13: 245–246, 1933.

[2] W. S. Baer, *Jour. Bone and Joint Surg.*, 13: 438–475, 1931.

the Army and Navy could provide, attracted Dr. Baer's attention. When he removed the clothing from the wounded parts, he was surprised to find the wounds teeming with thousands of maggots, presumably those of the blowfly. And when the wounds had been irrigated with normal salt solution, he was even more surprised to find that instead of being filled with pus, which he expected as a result of the degeneration of devitalized tissue and the presence of numerous types of bacteria, the wounds were filled with a healthy pink granulation tissue; there was practically no bare bone to be seen; and the inside surface of the injured bone, as well as the surrounding parts, was entirely covered with the same pink granulation tissue which filled the wounds. Bacterial cultures showed a few staphylococci and streptococci, but not enough to cause pus formation. The maggots had accomplished their task—the wounds had healed.

What Dr. Baer saw on the battlefield made a deep impression on him. Finally, after thinking about this experience for ten years, he decided to test by experiment the possibility of putting his observations into practical use in civil surgery.

In September, 1928, four children suffering from chronic osteomyelitis were admitted to the Children's Hospital School in Baltimore. Each child had previously undergone operation three or four times and had been treated over a period of from one to five years. On these children, who had been unsuccessfully treated by the usual methods, Dr. Baer began his first work in the treatment of osteomyelitis with maggots. First all the dead tissue was thoroughly removed from the affected areas. Then maggots of the blowfly, obtained from the immediate neighborhood, were placed without sterilization into the wounds. The maggots were replaced several times. At the end of about six weeks, the wounds had healed completely—the deeper structures as well as the skin.

The experimental treatments were continued. In the early treatments, however, difficulties arose from secondary infections. In three instances gas bacilli were discovered in the wounds. Although the patients presented no clinical symptoms of gas gangrene, all treatments were discontinued and research begun to solve the problem. From the experiments conducted, Dr. Baer was able to show that maggots destroyed rather than caused gas bacilli infection. And he concluded that in order to overcome gas bacilli it would merely be necessary to increase the quantity of maggots, after first making sure that the maggots placed into the wounds were free from all gas bacilli.

Following these findings, the treatment of wounds with maggots was resumed. But it was not long before tetanus (lockjaw) bacilli were found in the wounds of some of the patients. These wounds were quickly washed out, and the patients were given injections of tetanus antitoxin. Four patients manifested no clinical symptoms; two developed severe lockjaw; one, who had been suffering from advanced tuberculosis of the ankle, lung and spine, died in spite of the administration of large doses of antitoxin; and the last patient finally recovered after a long struggle with the infection.

From this disconcerting experience, Dr. Baer realized that in civil practice it would be necessary to use sterile maggots, and that in order to have at hand a supply throughout the year, flies would have to be grown successfully in the laboratory. After extended research a successful technic was devised for growing the flies and producing sterile maggots.

Dr. Baer continued with his maggot treatment of chronic osteomyelitis until April, 1931, when he suddenly died. Fortunately, he had observed and had treated a large number of patients, and

had been able to report 95 per cent. cures in children and 85 per cent. cures in adults. So excellent were the results he obtained that it was not long before many other surgeons adopted his method of maggot therapy. A recent report[3] shows that the treatment has been given in every state in the United States as well as in Canada and a large number of foreign countries.

Species of Larvae Used

The larvae used in maggot therapy are those that live only upon decaying and necrotic tissue. Satisfactory larvae are obtained from the bronze-green blowflies, *Lucilia sericata* (Meigen) and *L. caesar* (Linn.); the blue-black bottlefly, *Phormia regina* Meigen; and the large blue bottle-flies *Calliphora erythrocephala* (Meigen), *C. vomitans* (Linn.) and *Cynomyia cadaverina* Desv. Of the flies used, *Lucilia sericata* and *L. caesar* are the most satisfactory because of the ease with which they can be handled in the laboratory. Great care must be exercised to identify correctly the species of fly to be used, for the larvae of some species of flies are unable to distinguish between dead and living tissue and will feed as voraciously upon healthy tissue as upon dead tissue. The screw-worm flies *Cochliomyia macellaria* (Fabr.) and *C. americana* C. and P. are well-known examples of this.

Life History of the Fly

There are four stages in the life history of the blowfly, namely: (1) egg, (2) larval (maggot), (3) pupal, and (4) imago (adult). It takes from 10 to 24 hours for the eggs to hatch. The larval stage consists of two periods—(a) the active feeding and growing period, generally from 4 to 7 days, during which the larvae feed voraciously and are of surgical use; and (b) the prepupal or inactive period, usually from 3 to 4 days, during which the larvae do not feed and are useless for surgical purposes. The pupal stage generally lasts from 5 to 10 days. During this time the maggot undergoes transformation and emerges as a fly. On an adequate diet, the adult fly, as a rule, begins to lay eggs within 10 days after its emergence. Under laboratory conditions the life cycle of the fly is about 25 to 30 days.

Culture of Flies

Various methods of culturing both maggots and flies have been reported in the medical literature. The following procedure is the one most frequently employed.

The flies are reared in small cloth or wire cages which are kept in incubators maintaining a temperature of about 78 to 80 degrees F. and a relative humidity of between 40 to 65 per cent. The flies are given sugar, water and meat. Meat is an essential part of the diet, for without the presence of some nitrogenous material the female flies fail to develop sexually. This, however, does not apply in the case of the male flies. One feeding of meat is all that is necessary, and meat is subsequently added only when it is desired to collect eggs.

The flies continue to lay eggs well for about 3 to 4 weeks, after which time egg production and viability of eggs decrease. When this condition occurs the flies are destroyed and replaced by new colonies.

When new colonies of flies are to be established, the meat on which the eggs have been deposited is placed into a small glass feeding dish, which is in turn placed into a larger receptacle containing about an inch of sand. The outer receptacle is then covered to prevent the escape of the maggots after the eggs hatch. When the maggots are full grown (about 16 mm in length) they stop feeding, leave their food and migrate to the sand to pupate. When migration has ceased, the feeding dish and remaining food are removed,

[3] W. Robinson, *Am. Jour. Surg.*, 29: 67–71, 1935.

and the maggots are left undisturbed in the sand until pupation has occurred. When the flies emerge they are transferred to the brood cages and provided with food.

Culture of Sterile Maggots

The danger of introducing pathogenic organisms into the wounds with non-sterile maggots and the importance of employing sterile larvae in the practice of maggot therapy have already been brought to view under the discussion of Baer's early research. Aseptic bacteriologic technic is of the utmost importance throughout the entire process.

Before sterilization is begun the eggs, which are almost invariably laid in masses, are carefully separated so that the entire surface of each one is covered by the disinfectant. Separation is accomplished mechanically by agitating the egg masses in water or by carefully spreading them apart with a spatula. When separation is complete, the eggs are sterilized, generally in a formalin or mercuric chloride solution. After that, they are washed with sterile water and transferred to sterile food in glass containers. Here the eggs hatch into maggots, and the maggots feed and grow until they are ready for use. At the end of about three days' growth, the maggots reach a length of about 6 mm, the size desirable for surgical purposes. Before being employed in wounds, maggot cultures are tested for sterility, and those which show contamination are discarded.

Method of Treating Infections with Maggots

Before maggot therapy is instituted, the infected area is opened wide and thoroughly cleansed of all macroscopic debris and necrotic tissue. Minor infections need not be treated surgically. After the cleansing operation is completed, the wound is carefully packed with sterile vaseline gauze, which is left undisturbed for about 24 hours, or until all the bleeding has stopped, because maggots are repelled by blood and do not function well in its presence. When the packing is removed, from 200 to 1,000 maggots, depending upon the extent and condition of the infection, are placed into the wound. The wound is then covered with a wire screen, or with gauze, which is tightly fastened down to prevent the escape of the maggots.

The maggots feed upon the necrotic and purulent matter within the wound. In three to five days they reach their full growth and stop feeding. At this stage, no longer being useful, they are washed out of the wound with sterile salt solution. The patient is then allowed to rest for about 24 hours. At the end of that time, a new lot of maggots is introduced.

The length of time that maggots feed in the wound depends upon their size when they are implanted. The feeding period at the beginning of the treatment is longer than that toward the end of the treatment because maggots do not feed upon viable tissue and as the wound is cleaned up less food is available for them. When all the necrotic and decaying tissue has been devoured, the maggots die from insufficient nourishment.

The number of maggot implantations necessary depends largely upon the individual patient and the character of his wounds. The implantations range from 1 to 25, and sometimes more. For example, in children the healing period for chronic osteomyelitis of the long bones is about six weeks. In adults this period is at least a third longer.

Factors Effecting Cure in the Treatment of Infections

It has been found that maggots aid in the cure of infections in many ways. Among the important beneficial actions are the following:

(1) Since maggots feed upon decaying

and necrotic tissue, and so remove it from the wound, conditions for bacterial development are unfavorable. In their feeding, maggots also ingest numerous bacteria which are destroyed as they pass along the alimentary tracts of the maggots.

(2) During the course of the treatment, the wound secretes a thin, serous discharge which carries out with it great numbers of bacteria, thereby decreasing the number within the wound.

(3) The proteolytic end-products, which would otherwise be absorbed by the patient's system or remain in the wound and furnish a favorable medium for the bacteria, as well as the destructive bacterial exotoxin are ingested by the maggots and are rendered inert.

(4) The massage effect produced by the vermicular motion of the maggots on the granulating areas has been found to be a beneficial action.

(5) During the period of treatment there is a change from an acid condition, characteristic of infected wounds, to an alkaline condition. This change is effected by the production of ammonia as a result of liquefaction of necrotic tissue by the maggots and of the exudation of calcium carbonate through the body walls of the maggots. The alkaline condition thus produced is above the optimum reaction for the growth of many of the organisms associated with suppurative infections, and hence results in their destruction.

(6) It has been shown that allantoin ($C_4H_6N_4O_3$) and urea ($NH_2 \cdot CO \cdot NH_2$), found in the urinary secretions of maggots, have excellent therapeutic qualities.

Diseased Conditions Treated with Maggot Therapy

Table 1, prepared by Robinson,[4] is a summary of the various diseased conditions which have been treated with maggots. Robinson points out that they are

TABLE 1

Suppurative Infections Treated with Maggots
Abscesses, chronic
tubercular
Burns, with infected necrotic areas
Carbuncles
Cellulitis
Decubitus, sloughing
Empyema, chronic
Felons
Gangrene, arteriosclerotic
diabetic
gas
Grafts (infected), bone
muscle
skin
Mastoiditis
Osteomyelitis, acute
chronic—all bones
tuberculous
Periostitis
Ulcers, chronic
syphilitic
varicose
Wounds, infected
sloughing malignant

all of a purulent nature, and he states that maggots have generally not been found satisfactory for use in tuberculous bone lesions unless they were complicated by osteomyelitis. He further states that maggots have been used with some success for the removal of superficial, sloughing, cancerous areas, but not before necrosis occurs.

Discussion of Objections to Maggot Therapy

The most frequent objections to maggot therapy have been that the method is time-consuming, expensive and troublesome. Some objections have been that pain and discomfort to patients were often very great, and that the nervous tension experienced by patients with vivid imaginations at the thought of allowing maggots to feed upon them far exceeded the good that the treatment may have done. A few objections have

[4] *Ibid.*, p. 68.

been raised as to the efficacy of the treatment itself.

Although some of these objections may have been justified during the earlier period of maggot therapy, they are now no longer important because of the many improvements in the process of culturing sterile maggots and in the application of the treatment.

To reduce the cost of production of maggots, doctors living in the same vicinity rear maggots on a club plan. The author, in a recent study of an economical method of culturing surgical maggots,[5] has found that maggots can be cultured at a very nominal cost and without elaborate apparatus.

Pain[6] and discomfort, although never of a serious nature, have been greatly mitigated by the use of sedatives and by newer methods of applying the treatment. Since the psychological attitude of the patient is an important factor in the treatment, the fullest cooperation of the patient must be enlisted in order to derive the best results. Some surgeons believe that the method can be used more advantageously in patients of a low psychological type who are more or less indifferent to the presence of maggots. Other surgeons have expressed the belief that patients of higher intelligence and morale are the most desirable for treatment. Still other surgeons think that the method can be carried out most successfully when the patients understand and appreciate what is being done for them.

Concerning the efficacy of the treatment itself, its wide acceptance is sufficient proof of its merits.

Summary

One of the first observations that maggots were of aid in curing disease was made in 1557. However, it was not until the late Dr. Baer, in 1931, put maggot therapy on a scientific basis that the method became widely used in the treatment of suppurative infections. It is now considered by an increasing number of surgeons to be an inexpensive, simple and efficacious treatment.

[5] M. S. Tarshis, *Jour. Lab. and Clin. Med.*, 22: 1055–1061, 1937.

[6] Pain is usually the result of the exposure of nerves by maggot feeding.

PRIMITIVE FISH-HOOKS

By ELKAN J. MORRIS
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MAN in the first stage of his existence took much of his food from the water. If on certain stretches of land intersected by rivers, dotted by lakes or bordering on the seas, shell-fish, cetaceans and fish were found to the exclusion of land animals, primitive man might have been forced to depend upon the art of fishing.

After brute instinct, which is imitativeness, came adaptability. The rapid strides of civilization, considered in their material sense, are due solely to the use of such implements as are specially adapted for a particular kind of work. With primitive man this could not have been the case. Tools, whether they were axes, hammers or arrows, must have served the river-drift and cave-men for more than a single purpose. People with few tools adapt these to a variety of ends. The Kafir with his assegai fights his battles, kills his cattle, carves his utensils and shaves himself. It is only as man advanced that he devised special tools for different purposes.

According to our present acquaintance with primitive habits, if man existed in the later Miocene, and used a lance or spear for the killing of land animals, he probably employed the same weapons for the destruction of the creature—possibly of gigantic form—inhabiting the seas, lakes and rivers. The presence of harpoons made of bone, found in so many localities, belonging to a later period may not in all cases point to the existence of animals but the presence of large fish.

Following closely the advance of man, when his implements for fishing are particularly considered, we are inclined to believe he first used the spear for taking fish; next the hook and line; and later the net. It is possible that for a time he also used the bow and arrow.

Interesting as the history of primitive history is, we, however, occupy ourselves with the forms of the primitive fish-hook. The earliest form probably was a small piece of polished stone. The illustration (Fig. 1, a) was copied from one at the American Museum of Natural History. It was found in the valley of the Somme, France, in a peat bed twenty-two feet below the surface. The age of this peat bed has been variously estimated; later authorities, however, place it about 7000 B.C.

Wonderful changes have occurred

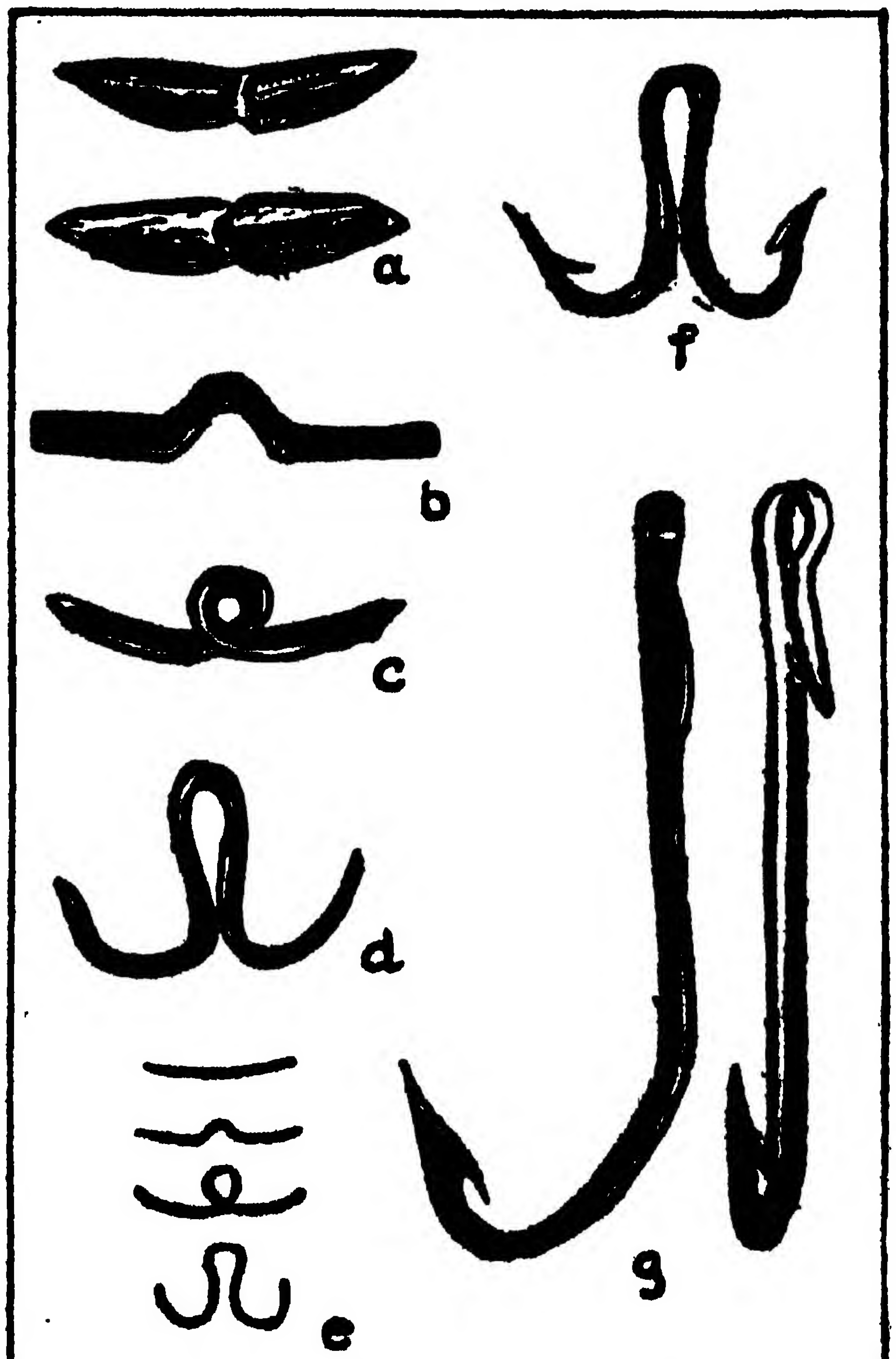


FIG. 1. *a.* STONE FISH-GORGE, FROM THE VALLEY OF THE SOMME. *b.* BRICOLE, FROM THE LAKE OF NEUFCHATEL. *c.* BRICOLE, OF A LATER PERIOD. *d.* DOUBLE HOOK, FROM THE LAKE OF NEUFCHATEL. *e.* PREHISTORIC FORMS. *f.* DOUBLE HOOK, BARBED, FROM SWISS LAKES. *g.* BRONZE FISH-HOOKS.

since this bit of polished stone was lost in what once was a lake. Examining this piece of worked stone, we find it fairly well polished, though the action of countless years has weathered its smooth surface. In the center a groove has been cut and the ends rise slightly from the middle. It must have been tied to a line and covered with bait; the fish swallowed it and the gorge coming crosswise with the gullet was captured.

The evolution of any present form of implement from an older one is often more cleverly specious than logically conclusive; nevertheless, I believe that in this case, starting with the crude fish gorge, I can show the steps that ultimately end with the perfected hook of to-day.

In the Swiss lakes are found the remains of the Lacustrine dwellers. Among the many implements discovered are fish gorges of bronze wire. When these forms are studied we notice they are copies of the stone gorges of the Neolithic period. It is fairly well known now that the early bronze worker invariably followed the stone patterns. The Lacustrine gorges have been named bricole. A bronze bricole (Fig. 1, b) found in the lake of Neufchatel is made of bronze wire and is bent in the simplest way, with an open curve allowing the line to be fastened to it. The ends of the gorge are very slightly bent, but were probably sharpened when first made.

A bricole which varies from the rather straight ones, found in the Lake of Neufchatel, belongs to a later period (Fig. 1, c). It is possible to imagine that the lake dweller, according to his pleasure, made one or the other of these two forms of fishing implements. As the double hook (Fig. 1, d) required more bronze, and bronze at first was very precious, he might not have had material enough in the early period to make it. This device is, however, a clever one, for a fisherman of to-day who had lost his hook might imitate it with a bit of wire.

When we compare the four forms, showing only the outlines, (Fig. 1, e) evolution of the fishhook can be better appreciated. Returning to the stone gorge, the work of the Neolithic period, it is evident that the man of that time followed the shape handed down to him by his ancestors; and as this fashioned stone from the valley of the Somme is of a most remote period, how much older must have been the Paleolithic fish-gorge of rough stone. It might have been with a splinter of flint attached to some tendril, in lieu of a line, that the first fish was taken.

In tracing the history of the fish-hook, it should be borne in mind that an overlapping of periods must have taken place. By this is meant that at one and the same time an individual employed tools or weapons of various periods. To-day, the western hunter lights his fire with a match. This splinter of wood tipped with phosphorus, the chlorates, sulfur or paraffin, represents the progress made in chemistry from the time of the alchemists. But this trapper is sure to have stowed away in his pouch, ready for an emergency, his flint and steel. The Eskimo, the Alaskan, shoots his seal with an American repeating rifle and, in lieu of a knife, flays the creature with a flint splinter. The net of the Norseman to-day is sunk with stones or buoyed with wood —certainly the same devices as were used by the earliest Scandinavian—while the net so far as the making of the thread goes is made by the most modern of mechanical appliances. Survival of forms require some consideration apart from that of material, the first having much the stronger reason for persistence. It is then very curious to note that fish-hooks not made of iron and steel, but of bronze or alloys of copper, are still in use on the coast of Finland.

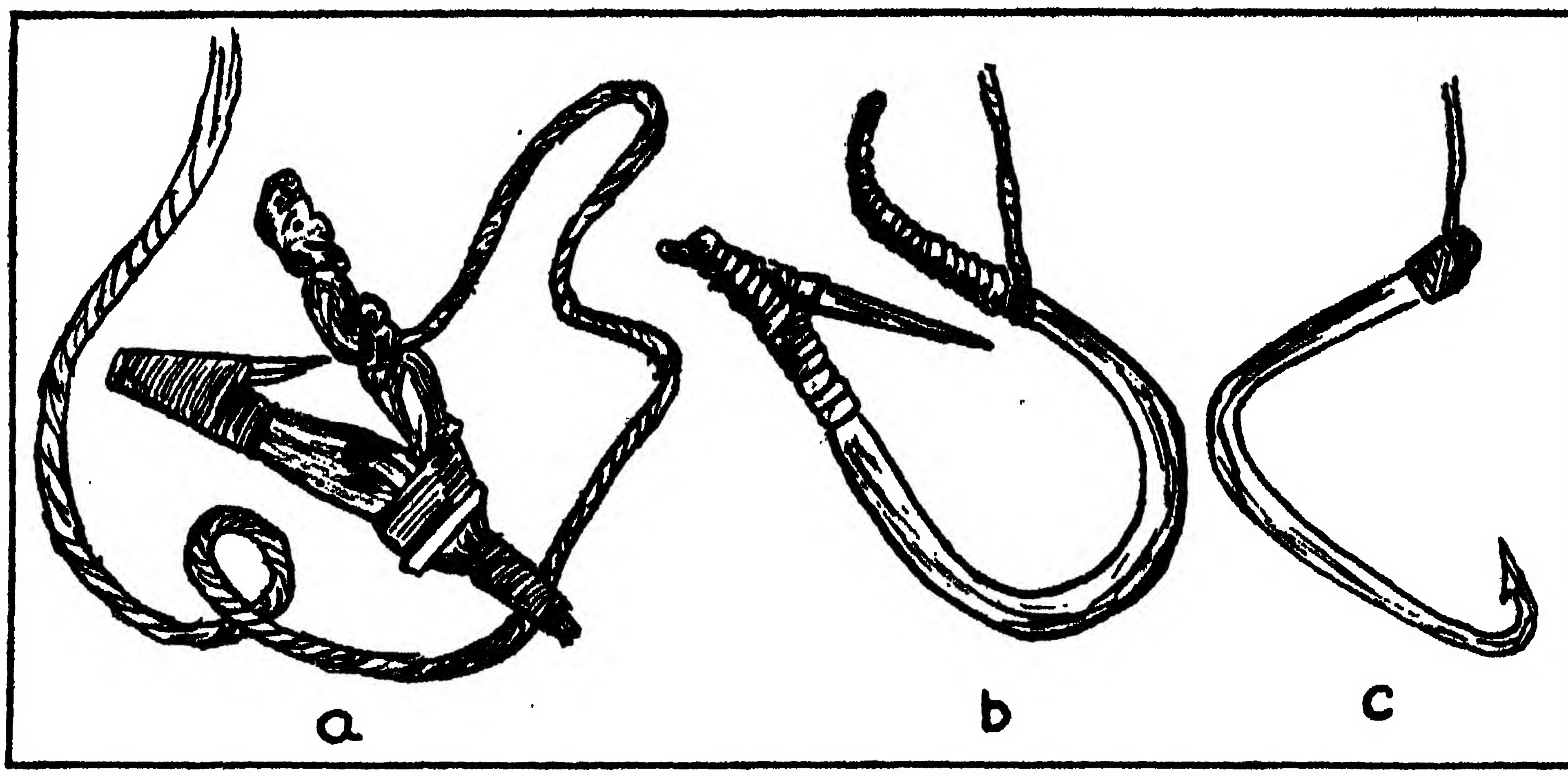


FIG. 2. *a.* ALASKAN FISH-HOOK. *b.* ALASKAN HALIBUT-HOOK. *c.* RUSSIAN FISH-HOOK.

The origin of the double hook having been satisfactorily explained, to make the barb on it was readily suggested to the primitive man, as he had used the same device on fish-spears and harpoons.

This double-barbed hook from the Swiss lakes is quite common (Fig. 1, f). Then, from the double to the single hook the transition was rapid. Single bronze hooks of the Lacustrine period sometimes have no barbs. Such differences as exist are due to the methods of attaching the line.

Hooks made of stone are exceedingly rare, and though it is barely possible that they might have been used for fish, I think that this is not conclusively shown. This, however, must be borne in mind; in catching fish, primitive man could have had no inkling of the present curved form of the fish-hook, which, with its barb, secures the fish by penetration. A large proportion of sea-fish and many river fish swallow the hook, and are caught, not by the hook entering the jaws, but because it is fastened in their stomachs. In the fisherman's language of to-day, a fish so captured is "poke-hooked"; and accordingly, when the representative of the Neolithic period fished in that lake in the valley of the Somme, all the fish he took must have been poke-hooked. A bone hook, excellent in form, has been found near the remains of a huge species of pike (Esox). Hooks made of the tusks of the wild boar have also been discovered with the Lacustrine remains.

In commenting upon the large size of the bone hook, its proximity to the remains of a large fish was noticed. When the endless varieties of hooks belonging to savage races are subjects of discussion, the kinds of fish they serve to catch should always be cited. In the examples of hooks which illustrate works of travel, a good many errors arise from the simple fact that the writers are not fishermen. Although the outline of the hook be accurately given, the method of securing it to the line is often incorrectly drawn.

In Fig. 2, b, an Alaskan halibut hook is represented. The form is a common one, and is used by all the savage races of the Pacific; but the main interest lies in the method of tying the line to this hook. Since the fish to be caught was the halibut, the form was the best adapted to the taking of this large flatfish; but had the line been attached in any other way then exactly as represented, this big fish could hardly be caught with such a hook.

In the drawing, the halibut-hook hangs but slightly inclining toward sea-bottom,

the weight of the bait having the tendency to lower it. In this position it can readily be taken by the fish; but should it be suspended in a different way, it must be seen immediately how difficult it would be for the fish to swallow it. In this Alaskan hook must be recognized the first idea of what we call to-day the center-draught hook. A drawing is also given of a steel hook of peculiar form coming from northern Russia (Fig. 2, c). The resemblance between the Alaskan and this Russian hook is at first apparently slight, but they both are constructed on the same principle. When this Russian hook is seized by the fish and force is applied to the line by the fisherman, the point of the barb and the line are almost in one and the same direction. Almost the same may be said of the Alaskan hook.

A study of these hooks—the Alaskan and Russian—show remarkable similarity to the modern, tempered steel, barbed hooks of the world to-day.

SPEEDING UP OUR READING

By Dr. WILLIAM BURNETT BENTON
VICE-PRESIDENT OF THE UNIVERSITY OF CHICAGO

We Americans pride ourselves on being a nation of readers. But despite our high degree of literacy, few of us actually *know how to read!* It doesn't matter much what our intelligence quotient is: most of us read no better than a child should in the eighth grade. More than half of all school failures are traced to bad reading habits; even scientists and scholars often read no more efficiently than day laborers without education. To put it quite bluntly, we are a race of "reading cripples."

Teachers and psychologists since the turn of the century have been trying to devise new and more effective methods of reading. Now, after 20 years of experiment and research, Professor Guy T. Buswell, of the University of Chicago, has perfected two machines by which our faulty reading habits may be diagnosed and cured.

A few weeks ago I visited Dr. Buswell's laboratory. He put me on a stool in front of a big rambling apparatus called the "eye-movement camera" that resembles the testing machines you see in the oculist's office. My head was fitted snugly into place on a chin rest. About a foot in front of me was a printed card. The professor told me to read it aloud. As I began reading, I heard the whir of a movie camera. A couple of inches from my eyes, and at one side, were two small mirrors, with a beam of light trained on each. The mirrors reflected the movement of my eyeballs into a long tube resembling a stovepipe. At the far end of the tube was the camera, making a movie record of my eyes as they worked.

When I finished reading the card, Dr. Buswell took the film from the camera. After an assistant developed and printed it, the scientist showed me the result: a series of short jagged lines, each punctuated by irregular jerks and jumps. "That," he said, "is the way you read. Each short line represents a line of type. Each jerk shows where your eyes jumped from one phrase to another."

I learned that as we read each eyeball is moved in its socket by six muscles so coordinated in their nerve connections that they move the eyes together in a beautiful example of team work. In reading, both eyes sweep across a line of print, not smoothly as you might think, but jerkily, in a series of kangaroo jumps, "fixating" successive points along the line. We ought to cover an ordinary line of type in three jumps. Most of us take six or eight. Some persons are able

to down a line in a couple of glances; but poor readers stumble along one word at a time, going backwards and forwards and making a dozen or more eye-swings to the line. Incidentally, we are blind while our eyes are moving; they have to *stop* to see. For maximum reading speed, these stops should be about one sixth of a second; actually many of us pause for a second or more; these over-long pauses and needless backswings of the eye retary our reading speed anywhere from 50 to 90 per cent.

I asked Dr. Buswell why most of us read so wretchedly. He explained that we had been taught wrong. Almost every man and woman over 35 learned to read in school by the oral method. Our teachers had us read orally, in order to teach us how to pronounce. Since we pronounced only one word at a time, we learden to *see* only one word at a time. As a result, most of us read no more than half as fast as we should—and with twice as much muscular work for our eyes.

There you have Dr. Buswell's diagnosis of our bad reading habits. But he is not satisfied merely with diagnosing them; he has devised a second machine to remedy them. This machine, a much less complex affair than the eye-movement camera, consists of a regulation home film projector and a small screen. With its help Dr. Buswell is ready to expose his "patient" to the cure.

The projector flashes a story on a screen. not a word at a time, not a line at a time, *but a phrase at a time.* Each phrase is about a third of a line. The "patient" practices how to absorb the phrase at a glance—one glance only. When he has mastered this, he is reading a line of type in three eye jumps—only half as many as before. Not only has he become accustomed to phrase-reading, but he is denied the opportunity to glance back.

The reading film projector can be operated at any speed. For the first lesson, Dr. Buswell flashes phrases at about the patient's customary reading speed, say 200 words a minute for half an hour. The next day the speed goes up to 225 or even 250. After 20 or 30 lessons a story is being run off at 650 words a minute for those who make the most progress.

Then another movie is taken of the "cripple's" eyes on the eye-movement camera. The difference in the two films —the "before" and the "after"—is often amazing: the latter test usually shows less than half as many jagged lines. The patient is reading twice as fast, and with less eye-strain! Dr. Buswell finds that some older people (many of his volunteer "guinea pigs" are over 60) can step up their reading speed almost as easily as the young. Exceptional cases have improved 100 per cent. in 20 lessons. A group of adults recently increased their average speed by 32 per cent. in 15 lessons. The normal adult, says Dr. Buswell, can easily learn how to read 500 words a minute and understand fully what he's reading. To-day, on an average, we read only about 300.

Do you ever wonder why your eyes tire easily? Do you think it's because you've read too much? More likely it's because you've wasted your eye-power. Listen to Dr. Buswell:

"Eyes were made for the distant view —for looking at sheep on far-off hills. When we focus them on something close, like a newspaper of a book, we make their muscles tense. And don't be fooled. Those eye jumps are hard, muscular work. Figure them up and you'll find that your eyes make 240 jumps to cover a single page of a book. Try wriggling your finger 240 times, and you'll understand how often your eye muscles get a work-out on every page."

Some day, reading projectors like Dr. Buswell's may be standard equipment in schools, libraries and adult education centers. But for those who can't wait

until then, who want to start their eye-improving at home right now, the professor has a few pointers:

(1) When you read, don't "vocalize," that is, don't say the words to yourself. Vocalizing is to reading what the hunt-and-peck system is to typing.

(2) Try always to recognize whole phrases at a glance, instead of single words. Not all people read phrases in the same word-combinations, so you'll probably develop your own groupings. Rhythmic reading is *good* reading. A metronome, or even beating time with the hand, helps at first in acquiring smooth, even eye jumps.

(3) Push forward. Force yourself to read at a pace a little faster than is comfortable. "You're never learning when you're comfortable," says Dr. Buswell. At first you may find yourself back-tracking oftener, but soon you will become accustomed to the new speed.

(4) Approach your reading with an attitude of genuine concentration. The more purposeful your reading, the more rapid it will be.

Mere improvement in one's technique of reading is no guarantee that a person will have a richer, more meaningful reading experience. But experiments by Dearborn of Harvard and Dodge of Yale have shown that reading becomes more pleasurable and profitable when the optical difficulties accompanying it are reduced to a minimum. If we don't know how to use our eyes, we learn painfully and only at a snail's pace. Speeding up our reading means speeding up education—not only in school, but in later life. Of course this doesn't mean that we should "race through" our reading; pausing to reflect on what we've read is one of the most valuable parts of the educational process. But, as any one can see, that's quite another matter from reading laboriously and inefficiently, a single word at a time. Until large sections of the adult population learn to read more rapidly and skilfully they will be incapable of that independence of thought which comes only from a wide and intimate knowledge of the printed word.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

ELECTRICAL GENERATION AND X-RAYS

Faraday's discovery of electromagnetic induction was the most important event of the nineteenth century, declares Dr. Arthur H. Compton, University of Chicago Nobelist in physics.

Why? "Empires would fall apart, society would become disorganized, if the electrical machines based on Faraday's discovery were put out of commission."

The discovery of x-rays by Roentgen in 1895 is perhaps the greatest event within the lifetime of persons now living. What could be of more purely academic interest than extending the spectrum of electromagnetic radiation to a thousandfold shorter wave-length?

Dr. Compton compares the consequences of Roentgen's achievement with the dramatic events of the world war.

First consider death, he says.

Such data are hard to find. The war lords do not want them advertised. In the world war there were about 8½ million soldiers killed in all the armies, one fourth of the able-bodied men now living in the United States and Canada—a tremendous slaughter.

Yet of the 450 million people then living in the countries at war, Dr. Compton points out, some 50 million will have died of cancer. The lives of some three million others will have been saved from cancer by the use of x-rays and the radium which was discovered as a result of x-rays. If you add to these the considerably greater number whose lives have been saved by the x-ray diagnosis of tuberculosis, a broken bone or an infected tooth, it becomes evident that even in the warring countries x-rays will have saved as many lives as were taken in battle.

X-rays have also had their great economic and political effects, not so dramatic as those of the war, but perhaps even more far-reaching. What does it mean to the economic and political life of the United States to be integrated by radio? Yet without x-rays, no radio. For the radio is the child of the electron, and the electron owes its recognition to the ionization of the air by x-rays. Similarly, were it not for x-rays we should not now have sound movies or long distance telephony, or radio beacons to guide air mail, or a multitude of other devices that rely upon electrons for their operation.

BASIC RESEARCH IN INDUSTRY

Research is one of the most used, and most abused terms in the English language to-day. Dr. Karl T. Compton, president of Massachusetts Institute of Technology, has defined it—in its simplest terms—as the application of all available knowledge and techniques for the systematic search for new knowledge.

One of the hardest jobs of scientific leaders is to convince industry, at least large portions of it, that research pays in the long run and that new knowledge is the springboard from which is launched future progress of the nation; industrial and otherwise.

One of the commonest short-sighted habits of a company is to apply what is called research to improve existing products, while, at the same time, basic long-range research is neglected.

In a recent address Dr. Compton presents the difference in the two pictures. Suppose a hundred years ago, he said,

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

an industrial laboratory has set out to develop more efficient types of lamps. It would have studied flames, oils, wicks, chimneys and so on. But it almost certainly would not have studied magnets, the properties of metals, electrical currents and high vacuum.

Yet it is out of such studies in pure research that have come modern lighting and communication by wire and radio. The King of England is once said to have asked Michael Faraday of what use were his experiments with compasses, magnets and wire. To which Faraday replied, "Your Majesty, of what use is a baby?"

In many ways applied research, making present things better, is comparable with doctoring a grown man already in, or past, his prime. Fundamental research produces the "new baby," which may turn out to be another genius or intellectual leader; or—to keep the analogy straight—another new and powerful industry.

THE CANADIAN RESEARCH COUNCIL

One of the finest buildings in Ottawa, Canada's capital, houses the Canadian National Research Council, which to the Dominion is what the National Bureau of Standards is to the United States and what the National Physical Laboratory is to England.

It is a "cradle of industry" where new industries are born and nurtured and where old ones are rejuvenated. A company of scientists of all varieties is at work in laboratories within the building, while in various colleges cooperative projects are under way.

Storage and transport of food is being studied as an aid to Canada's commerce. New developments in agriculture are being applied.

Plant hormones that speed growing and may have important practical results are being manufactured and used experimentally. A new kind of barley, with promise of superiority over the original variety, has been produced by heating the seeds and changing their chromosomes. This is the first time that new and valuable economic plant characters have been produced by heat treatment.

To Canada forests are important and acres are being cut daily for paper and other needs. Scientists are looking forward to fast-growing poplar trees to replace the original forests. Canadian cytologists find that natural hybrids between European and native species, with exceptional vigor and some promise of disease resistance, have an extra set of chromosomes, those minute bearers of heredity within the germ cells. They expect to use this fact in breeding rapid growing trees.

Canadian aviation has been aided through the design of airplane skis for use in landing on the winter's snows. All sorts of things from farm windmills to laundry are being investigated in other laboratories.

In many projects that imaginary line between the United States and Canada is obliterated by cooperation between scientists working on the same problem.

RESEARCH ON INFANTILE PARALYSIS

Much research must still be done before infantile paralysis can be brought under control, it appears from deliberations of a group of experts who recently conferred in New York City. In fact, Dr. Thomas M. Rivers, of the Rockefeller Institute for Medical Research, told the group that:

Epidemics of infantile paralysis are caused by a filterable virus. However, all cases occurring in an epidemic of paralysis may not be caused by the same virus. Furthermore, different viruses may be operative in different epidemics.

This means that the muscles must be carefully handled and protected during the very earliest stages of the sickness.

"Skilful protection before wrong positions are assumed and weakened muscles overused or stretched has meant the difference between the resulting disability

and restitution to normal life," a report from the U. S. Public Health Service states.

In order to assist physicians, nurses, physiotherapists and parents in protecting muscles weakened by this ailment and in restoring them by proper exercise to full usefulness, this same government bureau has issued a lengthy bulletin giving detailed instructions on care during the period of recovery from infantile paralysis. One of the points emphasized in this bulletin and by authorities generally is the importance of not starting corrective exercises too soon. Another important point is to avoid the slightest fatigue during exercises.

Infantile paralysis is not expected to become epidemic this summer. It is never safe to make predictions about epidemics, but past experience shows that during epidemic years the number of cases usually increases sharply toward the end of May. With only the normal seasonal increase this year, public health authorities feel that there will be no more than the usual number of cases this fall and summer.

CHANCES OF A CHEMICAL CURE FOR CANCER

THE chances appear good that a chemical cure for cancer will, some day, be found. This hopeful view is justified by a review Dr. Carl Voegtlin, chief of the National Cancer Institute of the U. S. Public Health Service, recently gave of the present status of the chemical attack on cancer.

The future angle must be kept in mind, for so far there is no chemical cure for cancer and no successful method of treating this condition except by surgery, x-rays or radium. However, Dr. Voegtlin says that in the experimental chemical treatment of cancer, when mice, not humans, are the patients, "some suggestive results have been secured." Referring to the way one germ-caused disease after another has fallen under the attack of new chemical remedies, Dr. Voegtlin says "it may not be over-optimistic to look forward to the time when similar results can be achieved in the chemical treatment of neoplasia (cancer)."

Among the results achieved by various researchers, which Dr. Voegtlin believes indicate cancer might yield to chemical attack are the following:

The growth of spontaneous breast cancers in mice was arrested in nearly three fourths of the animals following injections of extract from the placenta or from the skin of embryos. In over one fifth of the animals the tumors actually grew smaller.

An old gout remedy, colchicine, a coal-tar chemical, arrests cell growth and recent research indicates that the growth of certain mouse-cancers can be checked by this drug.

Certain sulfur compounds have been found to have a definite growth-checking effect on breast cancers of mice.

When mice with another kind of cancer are given a substance obtained from one kind of bacteria, hemorrhage and regression of rapidly growing cancers occurs.

LINDBERGH GLASS HEART

Newest triumph of Colonel Charles Lindbergh's "glass heart" apparatus, in supplying oxygen along with the fluid it circulates to organs living outside the body, is accomplished by using blood of what might be termed a living fossil. And blue blood at that.

The creature that supplied the blood is a member of one of the oldest zoological aristocracies on earth, the horseshoe crab. Horseshoe crab shells are familiar to every stroller along the sea beach. They look somewhat like crabs, but are considerably more primitive, and they have a history running back hundreds of millions of years. They may even be ancestral to the rest of us, through a race of sea animals long since extinct, the ostracoderms.

The problem of supplying oxygen through the fluid in the "glass heart"

long had the experimenters stymied. They found they could not use hemoglobin, the red pigment of ordinary vertebrate blood, because it very quickly broke down into a compound that would not carry oxygen, called methemoglobin.

Then, relates Dr. Richard Bing, of Columbia University and the New York Presbyterian Hospital, it was decided to try the blood pigment of the horseshoe crab, a blue stuff known as hemocyanin. A lot of crabs had to be sacrificed to get a sufficient supply, for each crab yielded only about 100 cubic centimeters, or a scant half-teacupful.

The blood itself was not used, but the hemocyanin was extracted and purified through a long series of chemical steps. When it was added to the circulating fluid in the right proportions it worked quite successfully, keeping various mammalian organs like kidneys and thyroid glands alive for several days.

Hemocyanin contrasts oddly with hemoglobin in one respect. Hemoglobin containing oxygen is bright red, and when the oxygen is gone it turns blue. Hemocyanin is blue when oxygenated, and when its oxygen is exhausted it has no color at all.

A NEW SOURCE OF INSECTICIDE

Devil's shoestrings trail along the whole southeastern seaboard of the United States, from New England to Texas. They aren't of any use now, but in time to come a new American industry may start from them. Promise has been counted good enough, at any rate, to justify the spending of considerable research time on the project, by a team of six scientists. The U. S. Department of Agriculture tells what they found in a new technical bulletin.

Devil's shoestring is a plant. It belongs to the pea family, and it is known by such other names as rabbit bean, turkey pea and goat's rue. Botanists call it *Tephrosia*. It looks rather like a vetch, only bigger.

In the tough, woody roots of devil's shoestring chemists have found the same compound now obtained from the roots of derris and cubé, imported in quantities from the East Indies and tropical America, for use in making sprays to kill flies, mosquitoes and other insects. This compound is called rotenone. It is harmless to man and other warm-blooded animals, but deadly to insects; hence its popularity as a spray ingredient.

This discovery of rotenone in the roots of devil's shoestring does not mean that an all-American insecticide industry can be built up overnight. A great deal of pioneering research must still be carried out, paid for either by the government or by private enterprise. Probably the government will be called on to do this preliminary work.

Participants in the research reported in the new bulletin were A. F. Sievers, G. A. Russell, M. S. Lowman, E. D. Fowler and C. O. Erlanson, all of the U. S. Department of Agriculture, and V. A. Little, professor of entomology at the Texas Agricultural and Mechanical College.

DARWIN ON MAN'S MENTAL EVOLUTION

Darwin was not a complete evolutionist. In his famous book, "The Descent of Man," he considered the evolution of man's physical nature only, but neglected the mental and social sides, declares Dr. William E. Ritter, emeritus professor of zoology at the University of California and honorary president of Science Service.

Darwin recognized that these nonphysical aspects of man's life are definitely parts of his nature, and as such must have been as subject to evolutionary influences and resulting changes as his head or his hands or his language. Yet, says Dr. Ritter, "he never tackled the problem in a detailed way. He seems to have regarded it as metaphysics and as such quite unsuited to his special interest and ability as a student."

Dr. Ritter himself refuses to acknowl-

edge a gulf between the so-called physical and metaphysical. In his recent studies he takes the position that "knowing, thinking and understanding are kinds of activity as inseparable from living things as are nutritializing, metabolizing and reproducing."

Dr. Ritter regards as most unfortunate the rather general mode of regarding living things as mechanisms, because the more naive mechanists, at least, unconsciously make it almost impossible to look upon mental and social phenomena as being really parts of human nature. Their explanations either over-simplify them, almost to the point of denying their existence, or they set up a body-versus-mind dualism that is repugnant to sound philosophy.

This way of regarding living organisms as machines was started a couple of centuries ago by Descartes, a French philosopher. Worth noting, in Dr. Ritter's opinion, is the fact that Descartes was not originally a naturalist but a mathematician, therefore having a bias in favor of simple exact descriptions. Darwin, a "natural" naturalist, did much to initiate the modern drift away from the Cartesian mechanistic speculations.

THE INHERITANCE OF RHEUMATIC DISEASE

The idea that rheumatic disease runs in families is pretty old, but it takes on new significance in the light of recent studies by a research team from the children's department of the Johns Hopkins Hospital, the Johns Hopkins School of Hygiene and Public Health and the U. S. Public Health Service.

The figures reported by this group, Drs. Frances E. M. Read, Antonio Ciocco and Helen B. Taussig, show such a strong family tendency to the disease that it suggests a constitutional susceptibility to the condition. If scientists, following this lead, can find definite characteristics of body build or reaction which are associated with rheumatic disease or can learn the order in which cases develop in a family, it might solve some of the unknowns about this disease and even perhaps point the way to control.

The rheumatic condition under discussion is not arthritis, which also used to be called rheumatism, but the kind which appears as St. Vitus' dance, rheumatic fever or rheumatic heart disease. The seriousness of the problem is apparent from the estimate that rheumatic heart disease alone kills between 25,000 and 30,000 persons every year, nearly all of whom are under 30 years of age.

Germ infection is considered by most scientists to be the cause of the condition, but cold climate, dietary lack and poor living quarters have also been strongly implicated. The findings reported by Drs. Read, Ciocco and Taussig to the *American Journal of Hygiene* seem to throw some doubt on the environmental factors.

Rheumatic conditions were found much more often in brothers, sisters and parents of rheumatic patients than in those of non-rheumatic children. But the significant thing is finding rheumatic fever almost three times as often among uncles and aunts of rheumatic patients, and almost eight times as often among their grandparents as among uncles, aunts and grandparents of non-rheumatic children.

FOOD VITAMINS AND FREEZING

With modern canning and cold storage methods there is little or no loss to the vitamin content of foods. In fact in some cases of fruits and vegetables the canned variety may show a higher vitamin content than the usual "fresh" products that the ordinary housewife can buy at the market.

The reason is that, for vitamin C at least, the canned fruits, juices of vegetables are packed quickly at harvest before time permits the oxidation that results in vitamin C losses. The so-called fresh fruits and vegetables, sometimes stored for long periods, gradually lose

their vitamin C content and may be inferior, in this respect, to the canned varieties.

Such, in summary, is the finding of Professor R. Adams Dutcher, of Pennsylvania State College. He cited the following as the human needs for vitamins and the known facts about vitamin preservation:

Vitamin A is needed to aid in preventing infection, for normal vision and normal growth. It is preserved by cold storage. Canned vegetables compare favorably, in vitamin A content, with the fresh variety.

Vitamin B_1 acts as a nerve stimulant. It is not destroyed by low temperature storage.

Vitamin B_2 is required for the proper functioning of the gastro-intestinal tract and the maintenance of a healthy skin. Enough is not yet known about it to give evidence on the effects of canning or cold storage.

Vitamin C prevents scurvy, helps the preservation of normal denture and gives strength and elasticity to the blood vessels of the body. Proper canning and proper refrigeration tend to preserve it.

Vitamin D prevents rickets by aiding the proper utilization of calcium and phosphorus in the bones and teeth. It is very stable and presents no preservation problem.

Vitamin E is the anti-sterility factor in the diet, is quite stable to heat and is easily preserved at ordinary temperatures.

IMPORTANCE OF INTELLECTUAL FREEDOM

More important than the actual discoveries and inventions being made today is the preservation of the right to engage in research. For several years the intellectual world has been shocked and disturbed by repeated instances of eminent men of learning forced to leave their work because of intolerance of governments to race, politics, religion or other special view-points.

This has brought forth many protests, among them declarations of the British and American Associations for the Advancement of Science, the Rockefeller Foundation and various codes of ethics and protestations. In England the journal, *Nature*, has editorialized persistently to arouse the scientists to impending danger.

"If science and learning are to regain everywhere the immunity from interference or persecution to which they have been regarded as entitled in all civilized communities for several centuries, it will not be by the efforts of a minority of scientific workers." This is *Nature's* latest editorial warning.

"Science will only be reestablished in its unique place among the interests of mankind when scientific workers everywhere recognize their responsibilities and are prepared to make fresh sacrifices in the cause of intellectual freedom. They must educate their fellow citizens to the realization that science is a common interest of mankind, and that whatever may be the barriers or the difficulties or the struggles between them, civilized societies must accord a certain immunity and tolerance to those engaged in scientific discovery and learning.

"Besides this, there must be a widespread recognition by scientific workers of the normal conditions of tolerance and immunity for scientific pursuits in a civilized state. These restraints—not to meddle with or be dominated by divinity, morals, politics or rhetoric must be clearly understood and firmly accepted by scientific workers. The loyal acceptance of such a code of ethics or discipline is all the more important to-day, not only if objective research in the social sciences is to be pursued, but also if what is often termed the frustration of science is to be overcome."

EXPLORATION BY BALLOON

By Dr. JEAN PICCARD

DEPARTMENT OF AERONAUTICAL ENGINEERING, UNIVERSITY OF MINNESOTA

THE free balloon was invented in 1783. It was with a great feeling of adventure and only after live animals had been carried into the air and brought safely back to earth that men dared go aloft. As soon, however, as the free balloon was able to stay in the air for hours at a time, attempts were made to use it for exploration. This exploration extended in two directions: vertical and horizontal. First it was the observation of the upper atmosphere which attracted general interest. How high could man go and still live? How did the air differ from the air at the ground? What would the temperature be at great altitudes?

In the second half of the last century, when photography became possible under more general conditions the free balloon was extensively used for taking photographs from places which could not possibly be reached by any other means of transportation. It was at this time that "Captain" Spelterini brought down most remarkable pictures from the Alps. With a skill attained by few others, if by any, he could pilot his large balloon close to the Swiss glaciers and take most beautiful photographs. He was the first man who flew over the Alps and he was also the first man ever to fly over the Egyptian Pyramids and over the Sahara Desert.

At about the same time the Swedish explorer Andrée started his ill-fated expedition across the north polar wastes. He succeeded indeed in exploring unknown territory but, unfortunately, his balloon could not stay in the air as long as the bold aeronaut had anticipated. Andrée and his two companions died on their return trip by foot, and the results of their great flight were brought back to civilization only long after the tragic death of the three explorers.

During the first hundred years after its invention the free balloon had made the atmosphere well known to mankind and the possibility of navigating it by means of the dirigible balloon and later by means of the airplane might still remain a dream, had not the free balloon first shown the way.

In the years just prior to the world war several free balloon flights were made in order to check on phenomena like adiabatic compression, diffusion of gases, absorption and loss of heat. These flights, although not producing scientific results of revolutionary importance, showed, nevertheless, that the gondola of the free balloon could be transformed into a physical laboratory of great efficiency.

The free balloon, at this time, could not go very high, and for the exploration of greater altitudes one had to rely entirely on the pilot balloon and the sounding balloon. Both of these instruments are unmanned. The first one, the pilot balloon, does not even carry apparatus. It is observed by means of a telescope or a theodolite, and the only results it can give to the observer are speed and direction of wind at various heights. The second one, the sounding balloon, is a much improved instrument of meteorology. It carries various apparatus which automatically register their findings, usually on a revolving drum, so that the results may be read by the sender once the balloon has been recovered.

The discovery of the stratosphere by Teisserenc de Bort is entirely due to these sounding balloons. It was well

known from previous flights that the higher one goes the colder the air gets. The decrease is about one degree Fahrenheit for each three hundred feet. This is what is called the temperature gradient. To his great surprise the French scientist discovered that when a certain low temperature was reached no further cooling took place at still greater altitudes. (The theory explaining why there should be such a phenomenon was later given by Humphrey, of the U. S. Weather Bureau in Washington, and by E. Gold.) From his findings Teisserenc de Bort concluded, a little too hastily, that above a certain limit, about seven to eight miles high, the air was *completely* stratified. No vertical currents *at all* would take place there. This region was called the isothermal layer or the stratosphere.

This was the time when it was generally assumed that in the absence of any mixing of the air at great altitudes the various gases of the atmosphere would separate according to their densities. Some text-books of this period contain the amazing statement that the stratosphere consists mostly of hydrogen.

Fortunately, the same sounding balloons which had told us about the existence of the stratosphere were also able to bring down specimens of air which were then analyzed in the chemical laboratories. These analyses showed that the air from as high up as samples could be obtained had very nearly the same composition as it had at sea level. The truth is that the stratosphere, as first conceived by Teisserenc de Bort, does not exist. Small disturbances exist everywhere, even in the stratosphere.[1]

The only information about winds which we have from heights above the ceiling of the highest balloon has occasionally been obtained by observation of the tails of large meteorites. These observations also show that there is in the air no place of perfect calm. We know of no region in the atmosphere, high or low, where some mixing does not take place, and this mixing is always more important than the separation (by gravity) of the constituents of the atmosphere.

A substantial prize offered some thirty years ago by the New York sport enthusiast, James Gordon Bennett, did more than any other single factor to promote free ballooning all over the world. The great International Air Races and the training connected with them were for years the grandest thing one could see in sports. Unfortunately, they had to be interrupted during the world war. After the war, there were several reasons why free ballooning never attained its former popularity. It is true that the Gordon Bennett air races were resumed, and several active balloon clubs were developed, but never did free ballooning as a sport become what it had been.

One of the reasons was, of course, the ever-increasing success of the airplane. Not only did the latter promise to become of greater military and commercial importance, but the distance record and even the altitude record were taken away from the balloon. Only the uninteresting endurance record was not beaten by the airplane.

At this time, however, and very fortunately, the free balloon was again used for explorations of various kinds. The German airplane builders wanted to know exactly how the gasoline engine would behave at great altitues and in order not to complicate their investigation by the introduction of several unknowns at the same time, they carried their engine up in a free balloon, the men using oxygen masks for breathing.

The famous Michelson-Morley experiment was repeated in a free balloon by

[1] During his second stratosphere flight (1932), Auguste Piccard had a silk flag hanging 150 feet below the gondola. This flag was in motion during the whole flight, even when the barometer showed no variation of altitude and the balloon itself seemed to float in perfect tranquility.

Auguste Piccard. This Michelson-Morley experiment is among the most difficult experiments ever performed in a physical laboratory. The whole relativity theory depends on it and yet doubts had been expressed in some quarters about its findings. It was stated, specifically, that the results of Michelson and Morley would have been different if these two scientists had not confined their work to a laboratory built under ground but if they had placed their apparatus a few feet above the earth's surface. Auguste Piccard demonstrated that under the conditions under which he worked, *i.e.*, in a free balloon at 10,000 feet, the old findings were correct: the wave-length of light was independent of the direction of the light. This means, expressed in a more popular form, that there is no "ether drift." Auguste Piccard showed that it is not only possible to repeat the experiment in the limited laboratory built within the gondola of a free balloon, but that it is far easier in a free balloon to eliminate all possibility of error from outside influences. Instead of rotating the apparatus inside of the laboratory, he rotated everything, apparatus, laboratory, gondola and balloon. The measurements were made at night, of course, and there remained no outside influence which could act differently from different directions. The balloon, moved by two electric motors with two propellers, made 150 rotations per hour. All measurements were recorded on photographic films and the final readings were made later in the laboratory. This experiment demonstrated, once more, that the possibilities of the free balloon as an instrument for physical exploration were far from exhausted.

This kind of experiment could never have been made in an airplane. It needed the steady rotation around a vertical axis of utmost stability. There is, indeed, no better bearing than the spherical balloon floating freely in the tranquil air of the night, high above the cities, towns and country.

At about the same time, some twelve years ago, one nation after another adopted a new method for meteorological forecasts, the so-called Norwegian air-mass analysis method. The older, *i.e.*, the classical, method tried to forecast the weather by observing the weather map on which the isobars were drawn. The determination of these isobars or lines of equal barometric pressure was the result exclusively of observations made on the ground. The well-known unreliability of these older forecasts was taken as a necessary evil. The new method, however, is based on the understanding that the weather is not only the result of conditions prevailing on the surface of the earth, but that the weather forecaster must be given a complete description of conditions throughout the atmosphere, at high as well as at low altitudes. Furthermore, not only the pressure but also the temperature and the humidity of the whole air mass must be known. The amazing results of the air mass analysis method could not fail to make it be adopted by all weather bureaus. This gave, of course, a tremendous impetus to the development of sounding balloons. The sounding balloon is the instrument *par excellence* to inform us daily about temperature and moisture in the upper atmosphere.

The ordinary sounding balloon is made from pure rubber. It is closed, and while it rises, the hydrogen in it expands. The ascensional force remains constant during the whole flight. While the balloon gets bigger and bigger, it passes through air layers of lower and lower density. Therefore, while the balloon gets larger its resistance per square foot diminishes and, as a result of these two factors changing in opposite direction, the speed of the balloon remains practically constant during the whole ascent. There always comes a moment when the balloon can not expand any further with-

out exceeding its limit of elasticity. Then the balloon explodes invariably, and the instruments, attached to a parachute or to a second balloon not large enough to support them entirely, reach the ground safely.

It is not necessary for air mass analysis to have the sounding balloons remain at their ceiling over a long period of time, and, indeed, the rubber sounding balloon could not be made, without considerable transformation, to remain at its top altitude for any length of time.

The sounding balloon has also been used for other purposes than for meteorological work: Millikan in California and Regener in Germany used it to carry cosmic ray apparatus to heights never reached by man. In this field, however, the results which the sounding balloon may collect are very incomplete, and at the same time as Millikan and Regener perfected their methods of investigation, Auguste Piccard took once more to the free balloon for exploration. His aim was to reach a region where he would have nine tenths of the air below him and only one tenth above. There, of course, the atmospheric pressure is exactly one tenth of what it is here. The barometer, instead of standing at thirty inches as it does at sea level, shows only three inches of pressure. These conditions are reached at an altitude of about ten miles.

It was clear that no human being could live and observe at this reduced pressure even when breathing pure oxygen. Therefore a new gondola had to be designed. It was spherical and hermetically sealed. The air contained in such a gondola of seven feet diameter was sufficient to keep two men alive for a few hours only. For this reason, a complete air regeneration apparatus was put in the gondola. The temperature regulation was made by choosing proper painting inside and outside. The gain of heat by radiation from the sun is terrific, but the loss of heat by convection is also very great. In his first flight, Auguste Piccard suffered from heat. The inside temperature went up to + 104° Fahrenheit. During the second flight he suffered from the cold. The inside temperature went down to + 10° Fahrenheit. From these experiences he could, however, design a gondola which was bound to have a convenient temperature throughout the flight.

By using the system proposed by him, Mrs. Jean Piccard and the author in their flight from Ford Airport in Dearborn, Michigan, observed in the inside of their gondola a temperature slowly rising from + 55° on the ground in the early morning to + 67° F. at noon in the stratosphere, where the outside temperature was − 67° F. This was accomplished not by any complicated machinery but by the simple device of having a heat-absorbing black paint on the lower part of the gondola and by having the top painted white with a heat-reflecting paint. The dividing line between the two paints was six inches above the "equator" of the gondola. The inside of the gondola was entirely white. From now on no one in a stratosphere gondola needs to suffer any more from heat or cold at day-time.

The new gondola was, however, not the only alteration needed to transform the old free balloon into the stratosphere balloon. The design of the bag, the ropes, etc., and the method of inflation were very probably the more difficult part of the invention. A complete description of these problems as well as any detailed discussion of the gondola lies beyond the scope of this article. We must be content with merely mentioning them.[3]

Auguste Piccard and his associates were able to make three flights with their original balloon (1931, 1932 and 1934). More flights were made with similar but larger stratosphere balloons from Russia and the United States. The most important of these flights was the National

[3] Detailed description may be found in Auguste Piccard's book, "Auf 16,000 Meter," published by Schweizer Aero Revue, Ag, Zurich.

Geographic Society—U. S. Army flight of Stevens and Anderson (1935). While most of the other flights had as sole or main objective the investigation of cosmic rays at great altitudes, the last-named flight included many other investigations in its program (photography, spectroscopy, collections of air specimens, etc.). For this flight, as well as for the already mentioned flight of Mrs. Piccard and the author, most of the cosmic ray apparatus were designed by W. F. G. Swann and his collaborators at the Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa.

Among the various alterations and improvements of the stratosphere balloon, subsequent to the first flight by Auguste Piccard, two or three must be mentioned: first the construction of a valveless balloon by Max Cosyns, the assistant of Auguste Piccard. This system allows the pilot to release gas through a tube hanging down from the zenith of the balloon. This tube is always open. By changing the position of its lower end one releases the gas below any desired point in the axis of the balloon. This allows perfect stability at any altitude. Secondly, let us mention a valve, controlled not by a rope but by compressed oxygen. We owe this invention to Stevens. And finally, let us mention the use by the author of electric blasting caps for the instantaneous release of ballast. This method, which was much improved by Cosyns, makes it possible to keep the bulk of the needed ballast outside of the gondola and relieves the pilot from the work of handling this heavy material. These and other inventions have greatly added to the safety of the stratosphere balloon and to the tranquility of its occupants.

Photographed by Jean Piccard.
A GORDON BENNETT RACING BALLOON AT THE START FROM CHICAGO, 1933.

On these stratosphere flights since 1931 heavy and complicated cosmic ray apparatus were used. On one of the American flights, one of the apparatus alone weighed 600 pounds. On this same flight the balloon was successfully and constantly rotated while in the stratosphere. This allowed the observation of the east-west effect of cosmic rays, an effect in which physicists are greatly interested.

While these stratosphere flights, when properly prepared, are exceedingly safe for the explorers, they have the great inconvenience of also being exceedingly expensive. This is the main reason why, parallel with these flights, sounding balloon flights for cosmic ray investigation are still made. No sounding balloon can ever bring down results comparable with the results gained by a manned stratosphere balloon, but for the same money as needed for one "big flight" many sounding balloons can be released and the accumulated results of these many "little flights" will eventually be quite important. There is no real competition between the two methods of research. Each has its advantages, and each can bring down results which the other could not be expected to yield.

Modern meteorology is not satisfied with the old sounding balloon which automatically records its findings. Usually days, sometimes weeks or months pass before the balloon is recovered, if at all.

At best, it takes many hours before the balloon is found and the instruments read. The results, although scientifically of great value, can rarely be used for any weather forecast. Meteorology is therefore greatly interested in the radio balloon. This is a sounding balloon which does not record the reading of its instruments. It sends the results down immediately by radio. The readings are thus available in the laboratory minute for minute while the balloon is going up. In the meeting of the American Meteorological Society in Kansas City, Lange, of Harvard University, demonstrated the new system at the airport. As soon as the balloon had left the ground, the apparatus in the hangar began recording automatically the pressure (*i.e.*, altitude) and the corresponding temperature and humidity. All these data were therefore immediately available to the air mass analyst for his weather forecast.

Physicists have also started the use of the radio balloon for cosmic ray investigation. The results are still very fragmentary, but they are certainly very encouraging. Since for cosmic ray investigation we need a longer time of observation, T. H. Johnson and the author used sounding balloons made from Cellophane. The Cellophane is not elastic, and the balloon can be built with an open appendix like a manned balloon. With a rubber balloon this is not possible, since rubber always has a tendency to contract and to expel the gas unless the balloon is carefully sealed. The sealed balloon, as we have seen, always rises till it explodes.

The new Cellophane balloon looks very much like a manned stratosphere balloon. It is partially inflated and pear-shaped at the start. When it reaches its ceiling, gas escapes through the open appendix and a position of equilibrium is maintained. This condition of equilibrium is further improved by an automatic ballast apparatus which releases sand as soon as the balloon has a tendency to go down. After a predetermined number of hours, a small rip panel is opened which, automatically, starts the balloon on its return trip to earth. In this manner one can make sure that the ballon will land during the day-time. Two results are secured by this procedure: First, the balloon does not endanger airplanes by crossing their paths during the night, and secondly, the chances of recovery are considerably improved if the balloon is visible before landing.

THE START OF THE FIRST MONTGOLFIÈRE
ANNONAY, FRANCE, JUNE 5TH, 1783
REPRODUCTION OF AN ENGRAVING MADE IN 1783. FROM BOOK "AUF 16,000 METER" BY AUGUSTE PICCARD, PUBLISHED BY SCHWEIZER AERO REVUE, ZURICH, SWITZERLAND.

These Cellophane balloons are, of course, heavier than rubber balloons. They will not reach the greatest altitudes, but they will carry heavy loads to the base of the stratosphere, and they will travel horizontally at great distances and in this manner will give a true picture of

Copyright, Schweizer Aero Revue.

PHOTOGRAPH TAKEN BY AUGUSTE PICCARD FROM THE STRATOSPHERE ABOVE THE SWISS ALPS. ALTITUDE OF BALLOON 16,200 METERS. TO THE RIGHT: THE MOUNT FALKNIS. IN THE MIDDLE THE RHEIN RIVER WITH SAND BANKS ALTERNATINGLY TO THE RIGHT AND TO THE LEFT OF THE STREAM. IN THE LEFT UPPER CORNER THE WALENSEE (LAKE WALEN). THE PICTURE IS TAKEN LOOKING STRAIGHT NORTH. FROM BOOK "AUF 16,000 METER" BY AUGUSTE PICCARD, PUBLISHED BY SCHWEIZER AERO REVUE, ZURICH, SWITZERLAND.

the air mass movement. A Cellophane balloon of this kind (fifteen feet in diameter) was released in June, 1936, from Minneapolis by the Department of Aeronautical Engineering of the University of Minnesota. It traveled to Arkansas and landed 613 miles from its starting point. The Cellophane balloon has its place beside the rubber balloon. While rubber balloons can only be made in the factory, every one can make his own Cellophane balloon as large or as small as he wants it. The toughness of Cellophane is such that, making the balloon a little larger than ours, it would allow its use by man.

The use of non-elastic Cellophane balloons for sounding balloons was, exactly speaking, an adaptation of the free balloon technique to the purpose of exploration by unmanned balloons. It is interesting to note that the reverse can also be done. We can indeed use the sealed rubber balloons to lift man himself into the stratosphere. By doing this we give up certain advantages of the open-neck free balloon, but we make use of other advantages offered by the rubber sounding balloon. The main advantages of this proposition are the low cost of an expedition and the great height which can be reached. Since single sounding balloons can not be built large enough to lift a gondola containing human beings, a cluster of these sounding balloons must replace the single bag. This introduces a new and most welcome condition for the pilot and the crew: a considerable increase of the safety factor. A single rubber balloon might burst at any moment, but the probability that out of three or four thousand balloons a considerable number would explode at the same moment is, statistically speaking, zero.

It is easy to demonstrate mathematically that the ratio of strength to weight is far more advantageous for the sounding balloon than for the open-neck free balloon, and the dangers of a failure at the start are considerably smaller. It

must be conceded, however, that a manned stratosphere flight with sounding balloons is so much at variance with the use of the orthodox free balloon that even if all the details can be calculated to the entire satisfaction of the engineer there still remains for the pilot an element of doubt which can only be overcome by experience with the new device. In other words, the new type of aerostat should first be tested under most favorable conditions. For this reason the Kiwanis Club of Rochester, Minn., sponsored such a test flight by the author. In order that the pilot could keep greater liberty of action in the case of unforeseen incidents it was decided to use an open basket and to remain below the limit where breathing atmospheric air might become difficult. The author decided also that his trusted pilot, Mrs. Piccard, should remain on the ground and concentrate her activities on the organization and command of the ground crew. The flight itself could easily be made by the author alone. The flight of the "Pleiades," as the aerostat was called, took place on July 18, 1937, and gave the desired proof of the navigability of the new aircraft. At the start the "Pleiades" consisted of two clusters of about 46 Dewey and Almy balloons each. For the descent and for the landing about 15 balloons were either released, stabbed or shot and after the landing the whole upper cluster was freed by the detonation of a T.N.T. fuse.

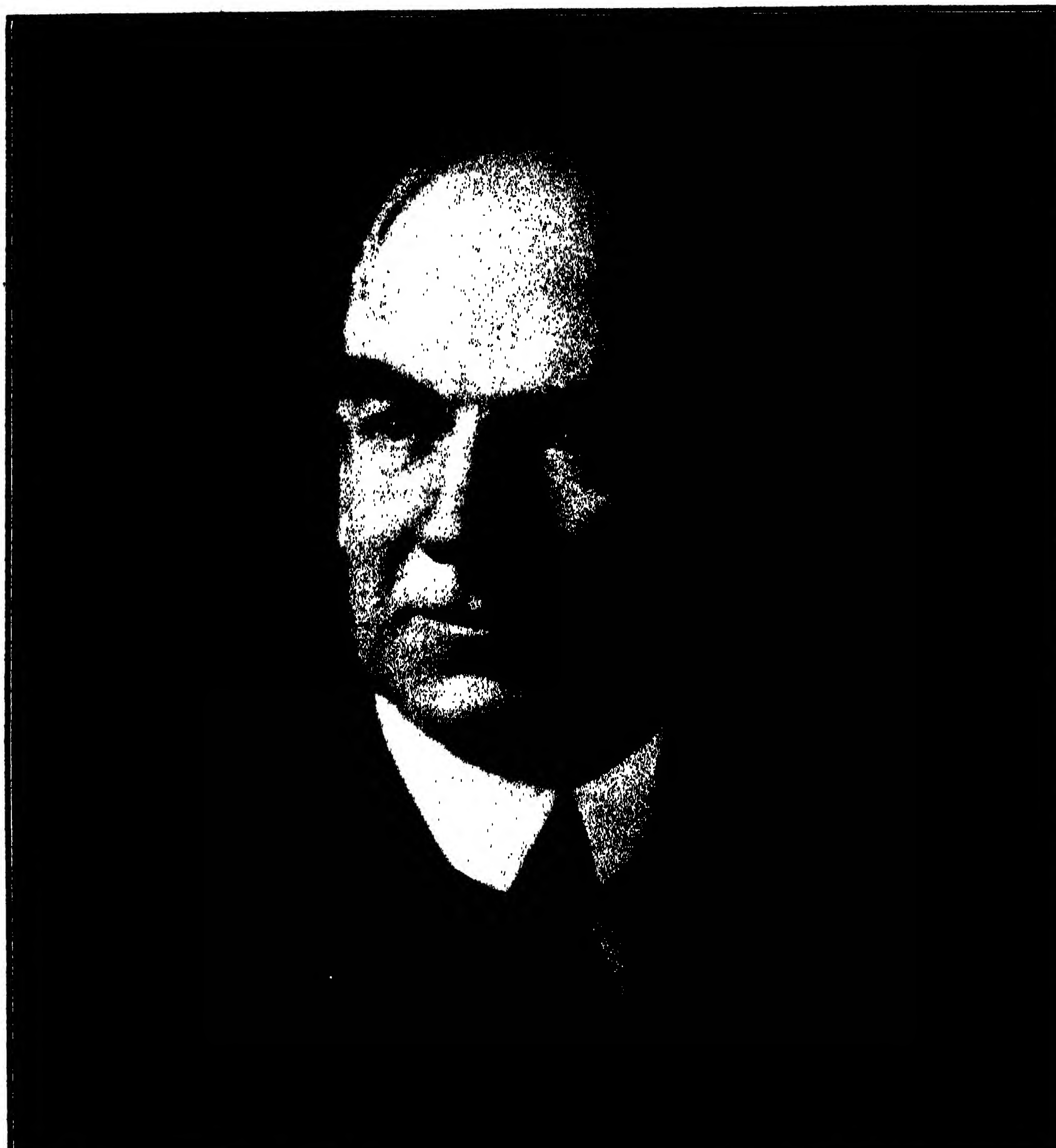
The Future

We have now at our disposal a large variety of instruments for the exploration of the atmosphere and especially of the stratosphere. We do not know if any of these instruments will ever be able to supplant the others. It is possible but not likely. For a long time to come the exploration of the stratosphere will go on and all available methods will be used. The investigation of the cosmic rays is of prime importance to science. There is in the universe as a whole probably as much energy in cosmic rays as there is in heat rays and in light. Since cosmic rays come to us from the empty interstellar space or from faraway stars, the most significant results are obtained if the cosmic rays are studied at the place where they enter our atmosphere, the place where they are the most nearly in their original state.

A wealth of information, useful to all natural science, has already been brought down from the stratosphere, but the more we get, the more we want, and much more information is still there, ready to be brought down from the region where our planet and empty space meet.

But quite apart from the purely scientific interest in the upper air there is also, from a business point of view, an important reason why we must know more about the stratosphere. The commercial airplane, the most perfect instrument of peaceful intercourse between the peoples of the world, must fly high in order to fly safe. High above the clouds, in the eternal peace of the serene stratosphere, lie the high roads for future long distance communications. There is no bumpy air in the stratosphere, no rain or snow, no mountains to hit in the fog, and the deadliest of all enemies of the plane, the dreaded icing conditions, are absent every day of the year.

How high will man go eventually? Calculation shows that the airplane is not likely to go much above ten miles. The great stratosphere balloon, however, with its sealed gondola, is still far from having exhausted its possibilities. Auguste Piccard has an entirely new design for a large stratosphere balloon which is calculated to go to an altitude where the barometric pressure is only one hundredth of an atmosphere, 0.3 inches of mercury. This condition will be reached a little below twenty miles. This is also, approximately, the ceiling of the "Pleiades" type of aircraft. Above twenty miles stratosphere flying for humans will begin to be not only difficult but dangerous.



WILLIAM WALLACE CAMPBELL

FORMERLY DIRECTOR OF THE LICK OBSERVATORY AND PRESIDENT OF THE UNIVERSITY OF CALIFORNIA.

THE PROGRESS OF SCIENCE

WILLIAM WALLACE CAMPBELL

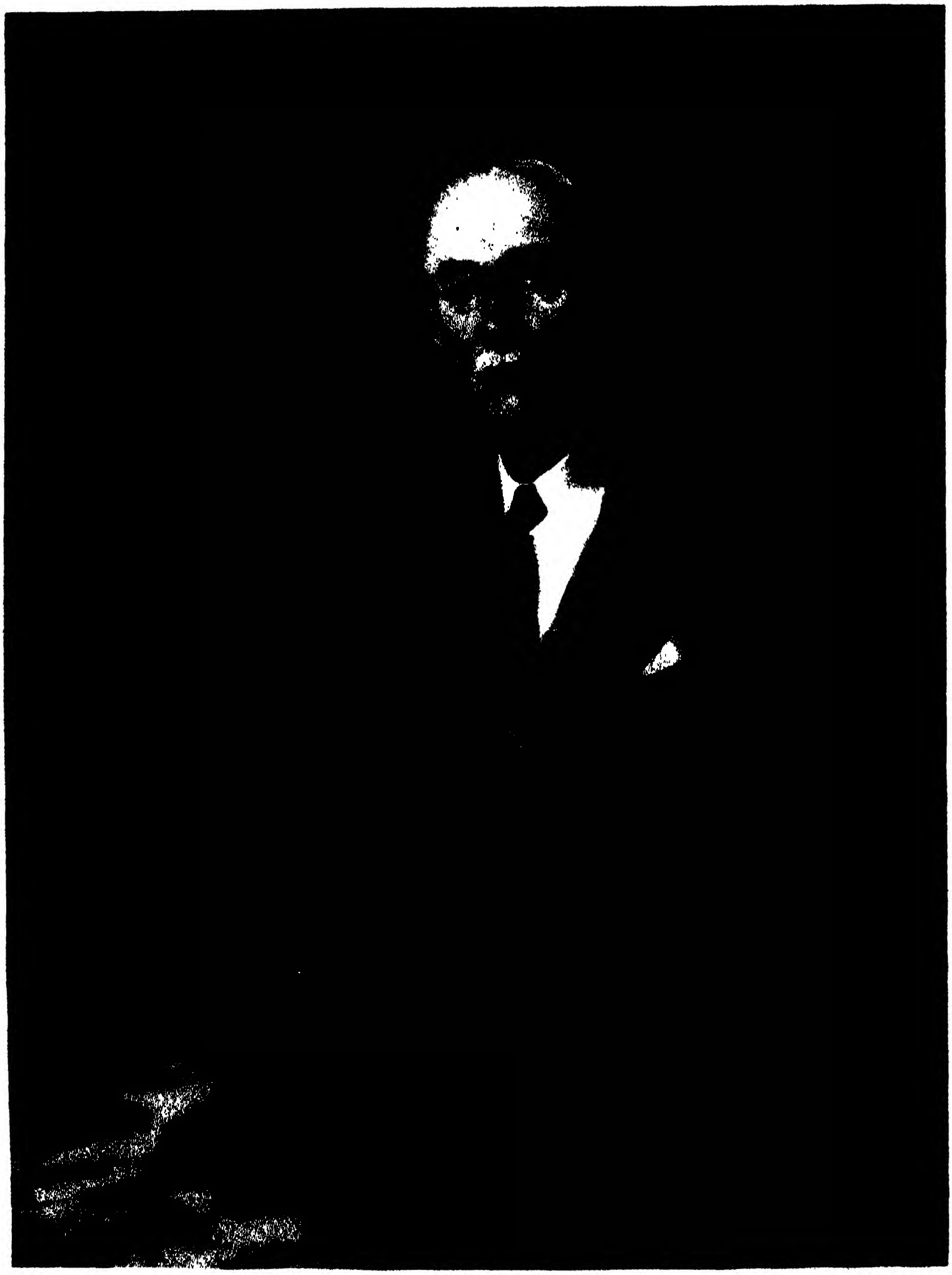
William Wallace Campbell, one of the great figures in America's university and scientific work, departed this life on June 14, 1938. One of his colleagues, Dr. R. G. Aitken, has written an appreciation of Dr. Campbell's life and work for a recent number of *Science*. A biography is to appear in due course from the National Academy of Sciences, and other tributes have been and will be paid to the services of our distinguished fellow citizen. The writer can not speak with authority of Dr. Campbell's work in astronomy, but can in his humble way say a few words in profound appreciation of his life and its significance to his country and his fellow citizens.

At the time of his death President Campbell had passed his seventy-sixth birthday. In that period of about three quarters of a century he attained with remarkable versatility achievements of first rank in teaching, in research and administration in one of the world's great observatories, and in the administration of one of America's great universities. Born in Ohio and a graduate of the University of Michigan, he passed in turn from a professorship of mathematics and practical astronomy through the positions of astronomer, director of the Lick Observatory and president of the University of California. He was in active service as the director of the Lick Observatory for a quarter of a century and in the presidency of the University of California for seven years. In the year 1915 he was president of the American Association for the Advancement of Science, and in the period 1931–35 he was president of the National Academy of Sciences. His honors, both at home and abroad, were many and distinguished. But these brief statements of fact signify merely his versatility and imply valuable service. They do not give us light on the really significant features of his labors and his contributions to America's progress. The really meaningful appraisal of Campbell's life and work can not omit reference to his magnificent character, to his unfaltering loyalty to the best standards of living and working which our halting civilization has thus far produced. As a result of many years of close friendship and official association, I can say that I have never known a man who was more genuine, more considerate, more helpful and more devoted to high standards of living and of working. His was a great spirit attuned to the eternal verities. He despised sham and silly pretense and never compromised with his conscience. This brought him at times much grief and pain, for our practical world is harsh, but he always stood by his guns.

Impressive accounts of Campbell's achievements have already appeared in the European press as well as in the American press. They pay tribute to his distinguished researches in astronomy, to his masterly conduct of eclipse expeditions, to his long and successful direction of the Lick Observatory and to the high standards by which he administered the teaching and research of the University of California. In the writer's opinion, however, the greatest of his services, and they have all been great, is the example of character, rectitude of purpose and action, unfaltering devotion to family, to country and decent standards of civilization, which he set for us.

He died as he lived—with lofty courage and with the thought of others taking precedence in his mind over thought for himself. We mourn his passing but rejoice with his family in the grand legacy which he has bequeathed to us.

Chas. B. Lipman
Dean of the Graduate Division
of the University of California



PROFESSOR CHARLES FREEMAN WILLIAMS McCLURE

PRESENTATION TO PRINCETON UNIVERSITY OF PORTRAITS OF PROFESSOR EDWIN G. CONKLIN AND PROFESSOR CHARLES F. W. McCLURE

On the afternoon of Baccalaureate Sunday, June 19, 1938, portraits of Dr. Edwin Grant Conklin, Henry Fairfield Osborn professor of biology, emeritus, and of Dr. Charles Freeman Williams McClure, Class of 1877 professor of zoology, emeritus, were presented to Princeton University. The occasion marked the fiftieth anniversary of Professor McClure's graduation from Princeton and the thirteenth anniversary of Professor Conklin's association with Princeton. The portrait of Professor Conklin was a gift to the university from many of his colleagues, former students and friends. Dr. McClure's portrait was the gift of members of the Princeton Class of 1888, colleagues, former students and friends. The two portraits, which are the work of Mr. John Young-Hunter, have been hung in the main hallway of the Biological Laboratories in Guyot Hall.

Dr. Livingston Farrand, formerly president of Cornell University and a graduate of Princeton in the Class of 1888, represented the donors in presenting the portrait of his classmate, Dr. McClure, to the university. In part Dr. Farrand spoke as follows:

This is not the time or place, nor am I competent to review in detail Dr. McClure's professional career and his contributions to biological science. It happens that I have been in a position to know something of his work in studying the development and comparative anatomy of the lymphatic system and the monographs and papers by himself and Huntington stand as classics in that region of biology. They exhibit that meticulous accuracy of observation and adherence to fact which have always characterized his work, and they form the basis of his later studies on the development of the vascular system, which field he has made peculiarly his own.

It is, however, another side of Dr. McClure's career at Princeton that I would emphasize. Something more than learning and mastery of fact is needed to make the great teacher. Certainly a fundamental aim of education is to arouse and establish in the student the spirit and habit of inquiry, and that Dr. McClure has accomplished in notable degree. Successive generations of Princetonians have been his beneficiaries.

And these rare qualities have been enriched by that straightforward, lovable personality that we, his friends of more than fifty years, know so well. His interest in others has always been genuine and constant, and hundreds of men of standing and influence in their communities look back with gratitude to what they gained from his teaching and friendship in their years as undergraduates on this campus.

Dr. George Packer Berry, a former student of Professor Conklin and a graduate of Princeton in the Class of 1921, represented the donors in presenting Dr. Conklin's portrait to the university. A portion of Professor Berry's address was as follows:

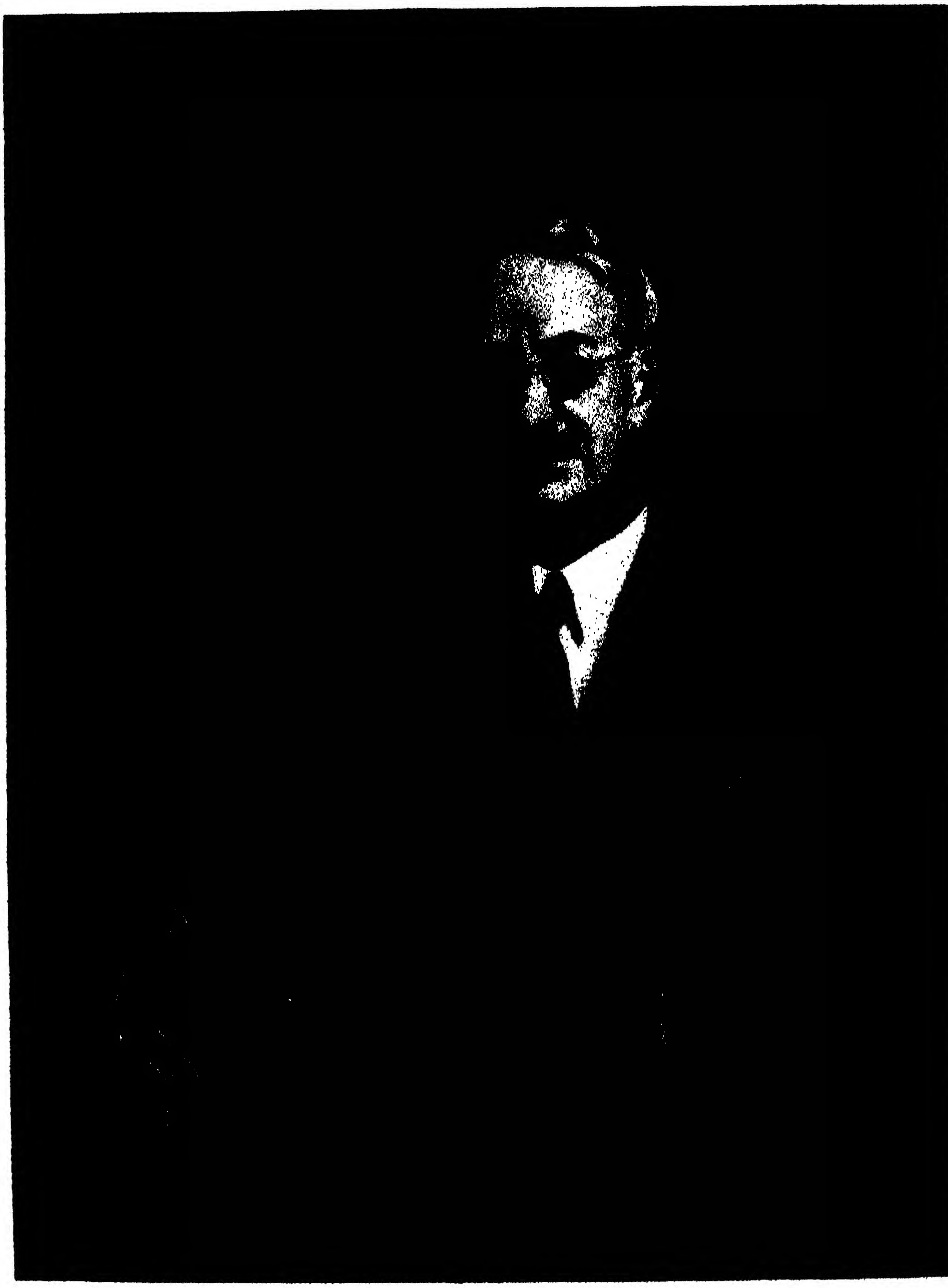
It is more than an honor and a privilege, it is a genuine pleasure, to present to Princeton University, on behalf of his many students, colleagues and friends, this portrait of Professor Edwin Grant Conklin.

How peculiarly fitting it is that a likeness of Dr. Conklin is to find a permanent place in Guyot Hall. For almost thirty years this has been the scene of his labors. Here he has built a renowned department. Here, as an incentive for all, his portrait will personify his ideals.

Dr. Conklin's investigations on cell lineage and the mechanisms of reproduction are classics and have had a tremendous influence on the development of embryology. His studies, characterized by extraordinary accuracy and insight, and presented with clarity and unusual artistry, have contributed enduring pages to the literature of science.

The philosophical implications of biological discoveries and theories for human affairs have always concerned Dr. Conklin. Nowhere has he expressed this interest more forcibly than in the far-sighted paper, "Science and Ethics," which he read last December as retiring president of the American Association for the Advancement of Science. By his extensive writing, even more perhaps by his addresses, he has brought the work of the scientist authoritatively before the public.

As a teacher, also, Dr. Conklin has attained great distinction. The stimulus which he has



PROFESSOR EDWIN GRANT CONKLIN

given to the students who have come under his spell is an immeasurable contribution to science. Indeed, there is no one in the whole group of biologists so widely known and so influential as he. His persistent idealism, his earnestness as a lecturer and his clarity of exposition have led many to share his enthusiasm for the study of living things.

In many respects, his course, "General Biology 201, 202," became the most significant one on the campus. It was frequently voted "most popular" by the undergraduates. His book, "Heredity and Environment," gave many a more penetrating insight into life. To-day, undergraduate and graduate students alike come in increasing numbers to Guyot. To how many of them has Dr. Conklin lent his ever-ready ear! The artist, Mr. John Young-Hunter, is to be congratulated for having appreciated in him this generous trait, this willingness to listen, and for having portrayed Dr. Conklin in what is to me one of his most characteristic attitudes, that of the sympathetic listener.

As a counselor, Dr. Conklin's mature advice has been sought far and wide. Since the beginning he has been a leader in the organization and conduct of the Marine Biological Laboratory at Woods Hole. His dominant influence in the American Philosophical Society has brought to that ancient and honorable body a new prestige. He has been president of most of the biological organizations to which he belongs. To each he has given devotedly of his time and energy. His seasoned judgment of men and affairs has profited greatly the scientific groups which he has served.

What of Dr. Conklin as a man? Little need to refer to this at Princeton! To know him is to love him. That says all. Investigator, teacher, administrator, counselor, human being—who shall say in which capacity his attainments are highest? In all directions his eminence is recognized. He has steadfastly adhered to the guiding principle of his life: "And ye shall know the truth, and the truth shall make you free."

In accepting the portraits on behalf of Princeton University, President Harold Willis Dodds said:

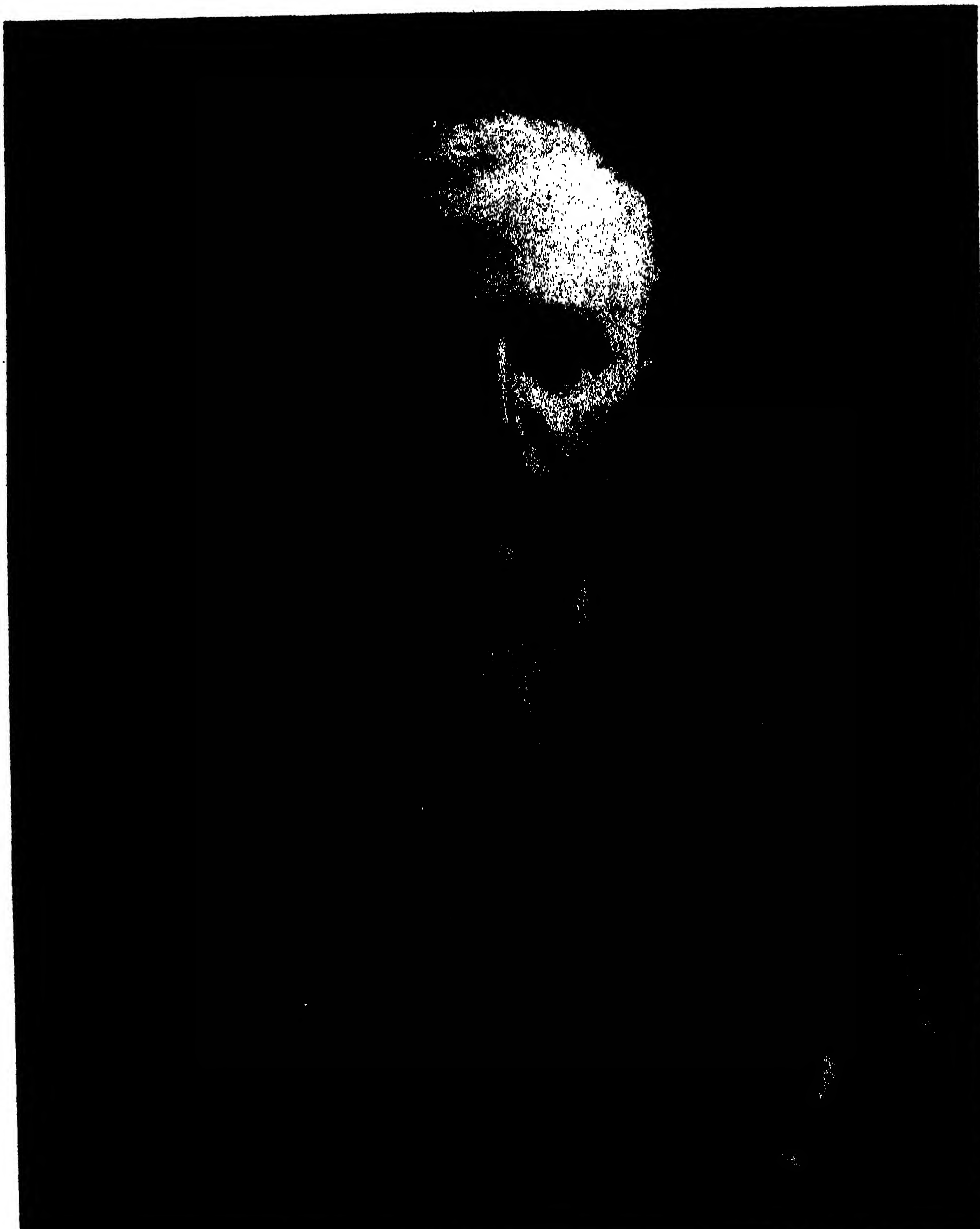
I am happy to accept in the name of the university these portraits of Professor Conklin and Professor McClure, the gifts of grateful students and co-workers of the past who by this method acknowledge their indebtedness to two great teachers. Others are better qualified than I to speak of their contributions to science. I want briefly to refer to them as personalities.

Professor Conklin's scientific attainments alone have earned him merited fame, but his career has also been important for other than his gifts as a scientist. Eminent as a pioneer on the frontier of scientific discovery, he has never been satisfied with any narrow definition of his vocation. Rather has his life emphasized the integral relation among science, philosophy and human welfare. Throughout the years in which academic influences were constantly pressing for greater and greater specialization, Professor Conklin kept insisting that science must be conceived in terms of human welfare and that the results of science must be articulated to human problems. Nothing that he has said represents this breadth of outlook better than his recent speech as retiring president before the American Association for the Advancement of Science. For myself, I herewith confess publicly my debt to the impress of Professor Conklin's thinking upon mine. His position in the world of thought is unique. May he live long to continue his remarkable influence.

The work of Professor McClure likewise can not be measured by his contribution to science in the accepted sense. For more than forty years following his graduation in 1888 he has been a loyal and effective member of our faculty, bringing to it welcome distinction. The results of his work can not be expressed alone by concrete additions to scientific knowledge. To me his great contribution has been the inspiration of his teaching, kindling in his students the flame of enthusiasm for science and leading them after graduation to continue the pursuit of knowledge in all the broad domain of science. In hundreds of students he has inculcated the discipline of science and respect for it. Literally hundreds of practicing physicians, for example, are to-day better scientists and therefore better physicians for having worked with him. To Professor McClure has been given the true reward of the gifted teacher, the assurance that he has transmitted his vision in ever widening circles to younger men equipped to carry forward the search for truth in years to come. As he retires from active service his colleagues extend affectionate regards and the hope that he may enjoy many years of health and happiness.

The world has need of scientists and teachers who exert positive influences molding forever the lives of their students. This high capacity is revealed in the two we honor to-day, and the university is proud to have been the instrumentality through which they have impressed themselves upon the lives of those who, desirous that the memory of two beloved teachers be perpetuated here, have given us these beautiful portraits. To the donors and to the artist who has worked with such understanding we extend our thanks for these expressions in oil of two great personalities.

ELMER G. BUTLER
CHAIRMAN OF THE DEPARTMENT OF BIOLOGY, PRINCETON UNIVERSITY



—*Photo from Wide World Photos.*

LORD RAYLEIGH

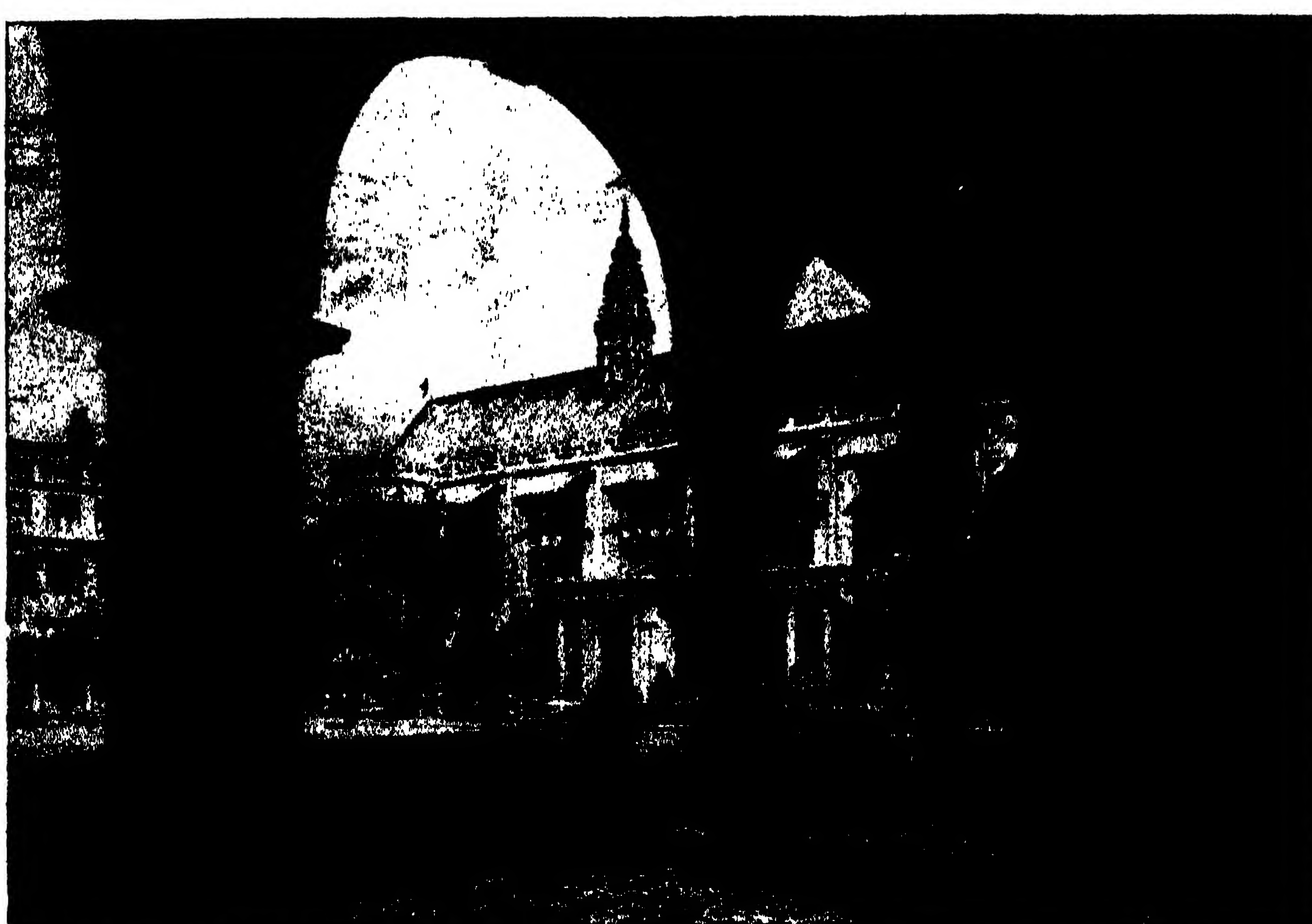
PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE CAMBRIDGE MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE British Association for the Advancement of Science held its annual meeting this year in Cambridge, from August 17 to 24. This is the fifth meeting of the association to convene in Cambridge and the second in the present century. Cambridge first received the British Association at its third meeting, held in 1833 under the presidency of the Rev. Professor Adam Sedgwick. The association met again in Cambridge in 1845, when Sir John Herschel was president, and has since convened in 1862 under the presidency of the Rev. Professor Willis, and in 1904, when the Rt. Hon. A. J. Balfour presided.

This year's president of the association is the Rt. Hon. Lord Rayleigh. He was president of the section of mathematics and physics in 1929 and president of the Physical Society 1934–36. His father, also a distinguished physicist, was president of the association when it met in Montreal in 1884.

According to the preliminary program, the inaugural general meeting of the association was to be held on the evening of Wednesday, August 17, in the Regal Cinema, when Lord Rayleigh was expected to deliver the presidential address on "Natural Vision and Vision Aided by Science." The address dealt with observational methods in modern science, pointing out their ultimate derivation from features of the structure of the human eye, and with the relation-



Etching by H. Toussaint

NEVILLE'S COURT, TRINITY COLLEGE

SIR JOSEPH THOMSON, FORMERLY CAVENDISH PROFESSOR OF EXPERIMENTAL PHYSICS, IS MASTER OF TRINITY COLLEGE. LORD RAYLEIGH, THIS YEAR PRESIDENT OF THE BRITISH ASSOCIATION, WAS A STUDENT OF THE COLLEGE, AS WAS HIS FATHER, THE LATE LORD RAYLEIGH, WHO PRECEDED SIR JOSEPH THOMSON AS CAVENDISH PROFESSOR OF EXPERIMENTAL PHYSICS. HE WAS PRESIDENT OF THE BRITISH ASSOCIATION IN 1884.

Etching by H. Toussaint

ST. JOHN'S COLLEGE

ships between science as a whole and modern warfare. Two evening discourses to members were to be given in the Arts Theater, the first on the evening of August 19 by Dr. H. Godwin, on "The History of the Fens," and the second on "The Contribution of the Electrical Engineer to Modern Physics," by Professor M. L. Oliphant on the following Monday evening, August 22.

The sectional meetings of the association began on Thursday, August 18, and continued daily, except Saturday, until August 24. Presidential addresses in the sections included a discussion on "Recent Investigations in the Chemistry of Gold," by Professor C. S. Gibson (Chemistry), "The Future Development of Oceanography," by Dr. S. W. Kemp (Zoology), "Correlations and Culture, a Study of Technique," by Professor T. Griffith Taylor (Geography), "The "Changing Outlook of Engineering Science," by Professor R. V. Southwell (Engineering), "The General Physiology of the Plant Cell and its Importance for Pure and Applied Biology," by Professor W. Stiles (Botany), and "The Proper Function of Administration in Public Education," by J. Sargent (Education). Sectional transactions embrace a very wide range of subjects, including recent developments in nuclear physics, the organic chemistry of metals, post-glacial history of the fens, soil conservation, cosmic ray research, problems in education and society, road and air transport, problems of modern engineering, low temperature research and many others.

CARYL P. HASKINS

THE SCIENTIFIC MONTHLY

OCTOBER, 1938

DEDICATION OF THE FRANKLIN MEMORIAL

IN HONOR OF BENJAMIN FRANKLIN

By Major THOMAS COULSON

THE FRANKLIN INSTITUTE, PHILADELPHIA

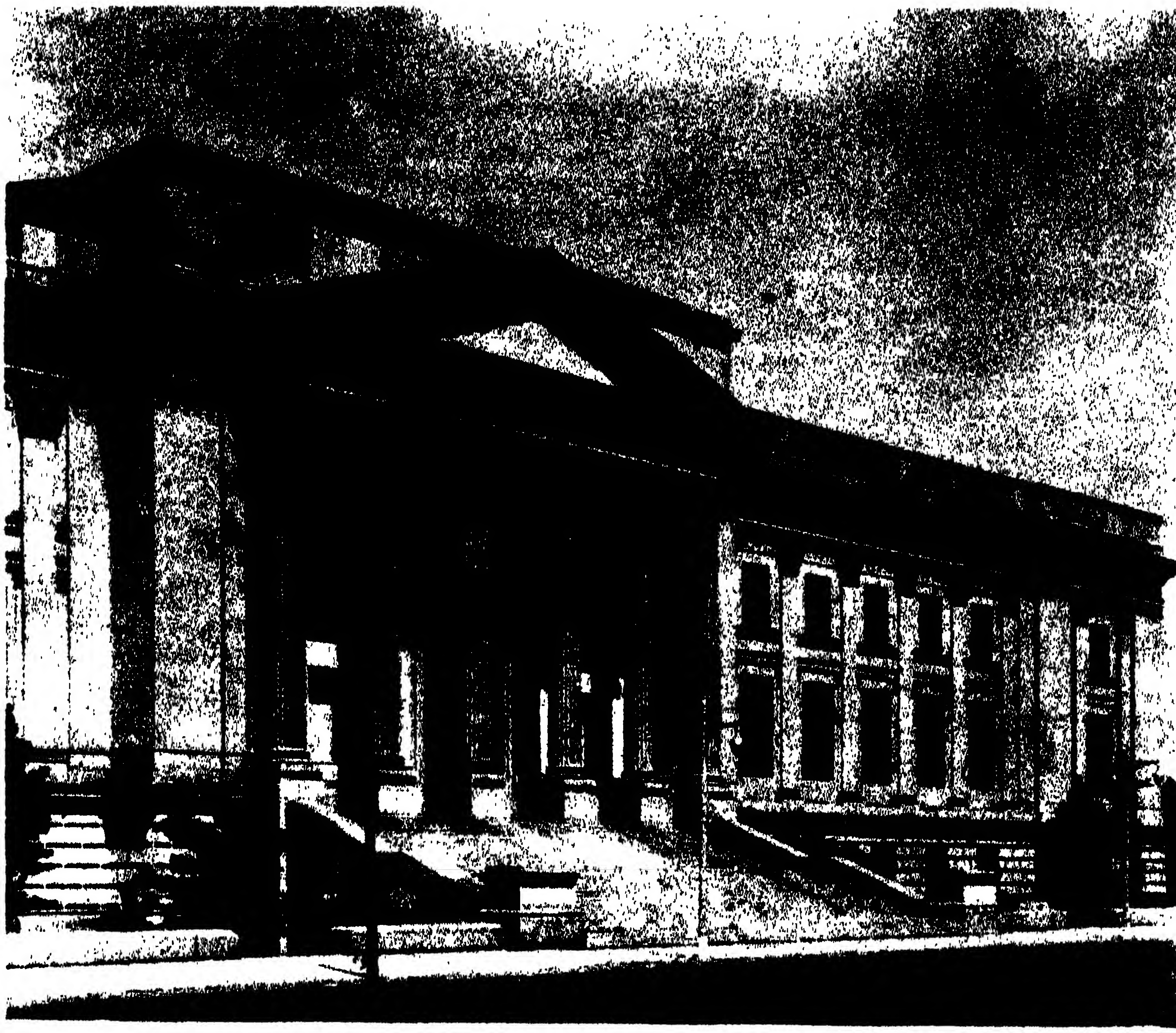
BENJAMIN FRANKLIN has been called the "typical American," but it would be more accurate to say that he was the only American whose personality fulfilled all the requirements of the Franklin type. An institution which proudly displays over its main entrance the legend: "In honor of Benjamin Franklin" must display a versatility and achieve a measure of success which will stamp it not only as truly American, but also as worthy of the great American whose name it bears.

No one knows why the Franklin Institute was blessed with that name. One hundred and fourteen years ago, when the Institute was founded, Franklin's memory was not held in high repute. That is not unnatural. His work was too great and too near to be seen in the proper perspective; time was required to permit a full realization of its value. The choice of name which now seems to have been so happy was a remarkable tribute to the foresight of those men who, during the presidency of Monroe, founded a scientific institution and called it "The Franklin Institute of Pennsylvania."

In the first decade of the nineteenth century the possibilities of obtaining a technical education were restricted to youths who were willing to undergo an apprenticeship to a trade. Knowledge was acquired by casual contact with journeymen, in conversation with fellow-workers and by technical operation. If the student wished to progress in his career he had to supplement this empirical knowledge by private and individual study. It was not realized that the scientific theory underlying practice must be taught and studied with understanding before it can be applied to the welfare of mankind.

At the time when the Franklin Institute was founded the industrial revolution was changing the conditions of our national life. There was a great quickening of thought produced by the introduction of machinery to replace hand labor, but the social adjustments necessary to adjust the growing industry to human needs had not been thought of. There were no technical colleges, no high schools; the Mechanics Institute was the sole dispenser of technical education. Unhappily this was only available to those who were indentured to industry.

Largely through the instrumentality of a young man, Samuel Vaughan Merrick, steps were taken to organize an institute which would provide qualified instructors to teach science to anyone who sought instruction, rich or poor, young or old, by night as well as by day,



Photograph by Gladys Muller

"IN HONOR OF BENJAMIN FRANKLIN"

THE NEW BUILDING, VIEWED FROM ACROSS LOGAN SQUARE. THE FLIGHT OF STEPS LEADS DIRECTLY TO THE FRANKLIN MEMORIAL HALL. THIS WAS ONE OF THE LAST GREAT BUILDINGS DESIGNED BY THE LATE JOHN T. WINDRIM, ARCHITECT.

and at a price within every one's reach. It was proposed to found a society of men whose reputation and special knowledge would fit them to investigate claims and to award certificates of merit to those inventors who were worthy of recognition. A modest conception of a museum was outlined. That was the beginning of "The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanics Arts."

How eagerly its early promise was recognized may be seen from the variety of occupations followed by the men who hastened to subscribe their names after the scheme was first advanced. Among the first twenty-one names are those of fire-engine maker (that was Merrick), merchant, brewer, teacher, saddler, plasterer, plumber, marble mason, clothier, shot manufacturer, druggist, counselor and blacksmith. So determined were these enthusiasts to serve the public that their haste to do good was almost unseemly.

The meeting of organization was called for February 5; by March 3 some four hundred and fifty members had enrolled; and by April the first professor of chemistry and mineralogy (Dr. William H. Keating) was delivering his lectures. Later in that year a school of architectural and mechanical drawing was flourishing, and within two years the first

high school was established. It is noteworthy that this high school became the model when the local authorities assumed responsibility for the higher grades of education. As the more liberal studies were provided for under the expanding public school system the institute began to confine itself to the more strictly scientific pursuits envisaged by its founders, and many courses were dropped, but the school for mechanical drawing continued for 99 years.

The lectures given before the institute membership have been continued in unbroken sequence since the foundation. At first they were of a character calculated to be useful to the elementary students. Soon they developed into reports on the progress of science and technology, and for many years these reports have been presented by those actually responsible for the progress. In that manner the institute members have been kept in close touch with the latest developments in science and the useful arts.

However, as the membership is distributed over the entire civilized world these lectures had to be made available through the medium of a printed journal. This was not the object of the founders. At the time when the institute was initiated scientific publications were expensive and hard to obtain. It was to break down just such difficulties that the institute had been formed, and it was determined that the members, students and apprentices should have equal facilities in reading at a reasonable cost. In August, 1825, was issued a prospectus announcing the forthcoming publication of *The Franklin Journal and Mechanics Magazine* under the editorship of Dr. Thomas P. Jones, professor of mechanics in the institute's school. Most of the earlier articles were abstracts or translations of interesting articles published alsewhere, but the publication of original work was soon commenced and has since remained the principal feature.

Dr. Jones displayed a special interest in patents which, in the rapid development of industry, were of increasing importance. Realizing that the official Patent Office publications were incomplete in the absence of the inventor's full claims, he caused to be published in the *Franklin Journal*, or the *Journal of The Franklin Institute*, as it has been called since 1828, an abstract of the specifications and the claims in full of all American patents. Thus the *Journal* is the only available source for reference to specifications *and* claims of patents issued between 1828 and 1842 (inclusive), after which the Patent Office extended its information.

The reason for publishing the *Journal* was likewise the motive for establishing the library of the institute—to make available to members the numerous books issuing from the presses to meet the demands of the quickened interest in the useful arts and their underlying sciences. At first the books and periodicals were stored at the residence of a member, but in 1829 a reading room was opened and quickly furnished with reading matter through the opening of exchange facilities provided by publication of the *Journal*. Through the course of the century of its existence this library has grown and expanded until it embraces a rich collection of 115,000 volumes and 40,000 pamphlets relating to science (excepting medicine) and technology. It possesses an invaluable number of complete "sets" of periodicals. As a research library it is unique in its field. This means that it is to aid in the production of ideas, not in their dissemination. It promotes invention and discovery.

One of the problems uppermost in the minds of the founders was the need felt by inventors for some competent, trustworthy and impartial body on whom they could rely for a judgment upon the usefulness of their inventions and discoveries. From the original board of

BENJAMIN FRANKLIN

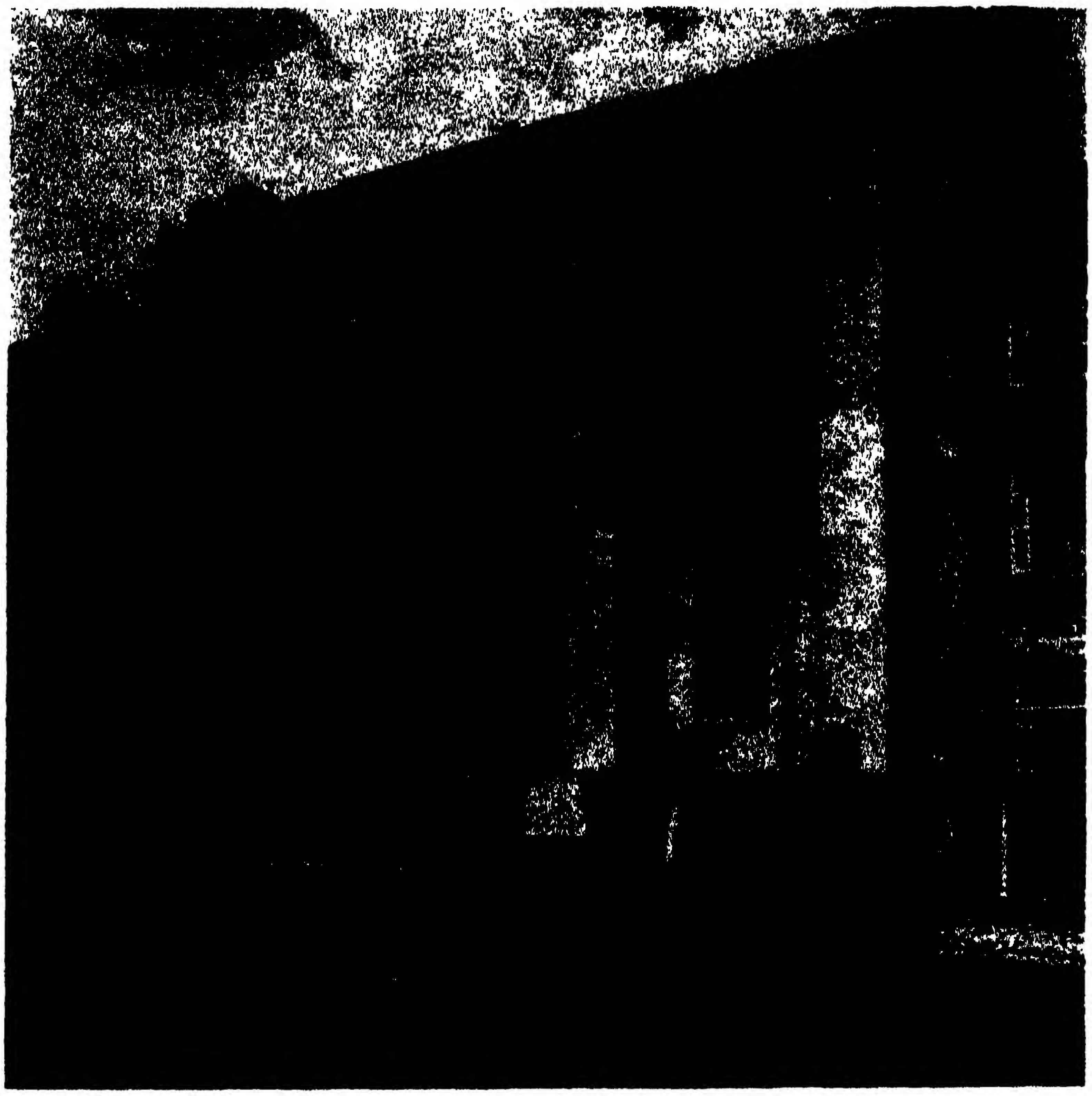
THIS SHOWS THE MODEL USED BY THE SCULPTOR, JAMES EARLE FRASER, IN THE PREPARATION OF THE GREAT STATUE OF BENJAMIN FRANKLIN AT THE FRANKLIN INSTITUTE. FROM THIS STATUE WAS DESIGNED THE NEW HALF-CENT POSTAGE STAMP OF THE UNITED STATES.

examiners appointed for this purpose has grown "The Committee on Science and the Arts" which examines and reports on all new machines, inventions and discoveries submitted to their consideration. In its earlier stages this committee acted as a body for providing wise counsel to would-be inventors by informing them of what had previously been accomplished in their various fields, and when any matter that was novel and of value came to their attention they endorsed it with their approval, thus aiding in securing public approval and reward to the inventor.

As the fame of the institute spread it became the custodian of several funds for furnishing medals of recognition to those men who were most prominent in advancing ideas for the improvement of scientific applications to the well-being of mankind, irrespective of country. Best known of these awards is the Franklin Medal for signal and eminent contributions to science. Among the more distinguished recipients of this medal have been Arrhenius, Bragg, Dewar, Edison, Einstein, Lorentz, Marconi, Michelsen, Planck, Rutherford, Thomson and Zeeman. Seven other medals are awarded annually for distinguished services to science, the industrial arts or for perfection of workmanship. An astonishing and impressive list of scientific and industrial giants could be compiled from the recipients of these medals. Among the names are those of Bell, Crookes, the Curies, De Forest, Diesel, Emil Fischer, Henry Ford, Frederick Ives, C. F. Jenkins, Chevalier Jackson, the Lumieres, Ramsey, Rayleigh, Rutherford, E. A. Sperry, Tesla, Elihu Thomson, Vauclain, Welsbach and Orville Wright.

Our contemporary life is studded with exhibitions. Periodically our leading industries break into a rash of exhibitionism, so that they may display in every detail the implication of their products upon our daily life. A hundred years ago, before industrialism had reached its adolescent stage, neither the manufacturer nor the public had realized the impending changes in living conditions involved in the development of processes, methods and machines; there existed no vehicles by which the public might learn how the manufacturer was trying to fill its needs nor by which the producer might inform the consumer of his achievements. Advertising was primitive. Yet, an organization of the nature of the Franklin Institute, directly and deeply concerned with the problems of science and its applications, could not long ignore the necessity for acting as the medium for educating both the manufacturer, the scientist and the buying public in the functions and relations which bound them to the pursuit of a joint end. Casting about for a means of providing a common meeting place for those concerned with the infant industries and the utilization of their products, the institute hit upon the idea, wholly original in those days, of organizing an exhibition.

In the first quarterly report of the Institute one reads: "It is confidently believed that when the products of our industry are collected from the various workshops now dispersed through the city and state, and exhibited together, they will form a collection calculated to excite a gratifying sense of pride . . . and an encouraging hope that under proper regulations, we may soon compete with foreigners in the manufacture of all useful articles." Before the year had ended the institute had organized the first exhibition of American industry and had displayed it proudly in the historic Carpenter's Hall. There had not been a great deal of time between April and October to make all the necessary preparations, but these early members were fired with a missionary zeal that worked marvels. A strange assortment of goods came from Maine, Rhode Island, Massachusetts, Maryland



THE FRANKLIN INSTITUTE ON SEVENTH STREET
ERECTED IN 1825, THIS OLD BUILDING WAS THE SCENE OF MANY MEMORABLE OCCASIONS DURING THE 108 YEARS THAT IT SERVED AS THE HOME OF THE INSTITUTE. IT STILL STANDS ON SEVENTH STREET, BETWEEN MARKET AND CHESTNUT.

and Ohio in addition to the immediate neighborhood of Philadelphia. There was plenty of variety in the exhibits, too, for medals were awarded for blister steel and grass bonnets, japanned goods and broadcloths, bar iron and carpets, among other more or less useful articles.

Much was learned from this exhibition, and the results were so encouraging that it was resolved to make the exhibition an annual feature of the institute's work. Later they became biennial, and subsequently they were held at irregular intervals, not because the institute was losing its interest in industry, but because the various industries were learning to stand upon their own legs, and specialized exhibitions were necessary to display the rich assortment of goods pouring from the nation's factories.

Before leaving the subject of these exhibitions a word must be said of one or two in particular. That of 1840 was notable for the fine display of Daguerreotypes, then an entertaining novelty. The fiftieth anniversary of the founding of the institute (1874) was celebrated by an unusually successful exhibition in which 268,000 visitors inspected the products of 1,200 exhibitors. A notable contribution to the joy of life was the introduction at this exhibition of the ice-cream soda, given to the world for the first time on this occasion. Great as was the popularity of this exhibition it was completely eclipsed in brilliancy and in value from both the educational

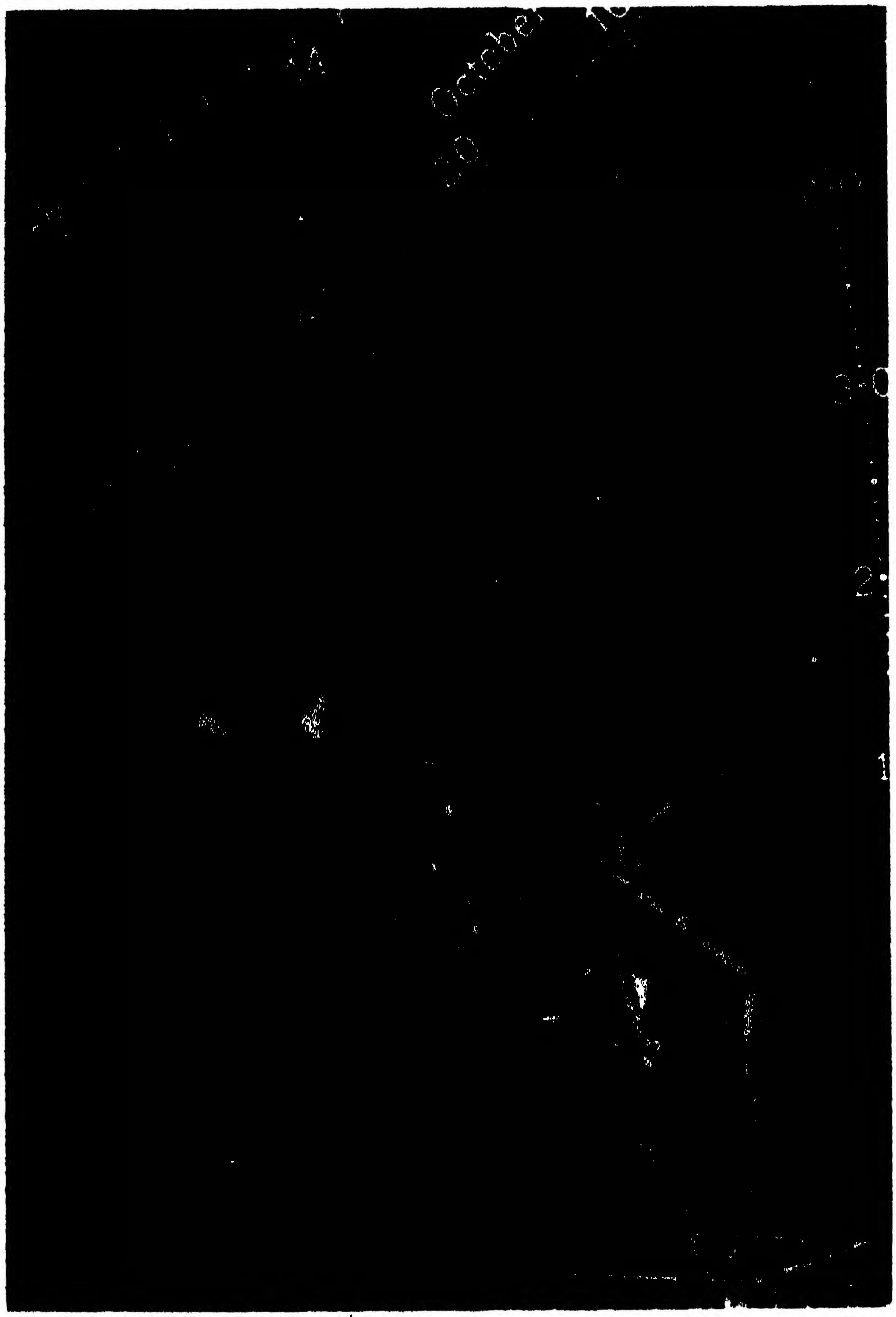
and technical aspects by the Electrical Exhibition of 1884, which was made international in character. This, the first electrical exhibition in this country, was conducted without any financial aid to the institute. It will be understood readily that fifty years ago the exhibitors from the electrical industry were restricted in number, but they lacked nothing in enthusiasm, which was communicated to the visitors, over 299,000 of whom examined the goods displayed. Men of such eminence in the electrical field as Lord Kelvin, Sir Oliver Lodge, Alexander Graham Bell, S. P. Langley, Elihu Thomson, E. J. Houston, Thomas A. Edison and Sir James Dewar were among the interested spectators or exhibitors.

At the present time the institute adopts a different policy in regard to exhibitions. Instead of organizing large displays occasionally, there is a continuously changing exhibition of the products of industry and invention in the spacious museum, of which we shall have more to say.

Once the Franklin Institute had passed through the first few years of feverish activity it barely had time to catch its breath before it was urged to undertake research and investigations at the request of federal, state and local authorities. It seems strange to think that so many of the functions of government departments were farmed out to this body of enthusiastic amateurs, who alone were qualified to discharge them. However, before the value of its labors had been recognized by the authorities the various committees of the institute had proved their worth. They had investi-

THE LECTURE HALL

IN THE OLD FRANKLIN INSTITUTE BUILDING. MANY IMPORTANT DISCOVERIES WERE ANNOUNCED OR DEMONSTRATED FOR THE FIRST TIME IN THIS ROOM.



Photograph by Gladys Muller

THE FELS PLANETARIUM

OPENED IN 1933, WITH JAMES STOKLEY AS DIRECTOR.

gated the subject of water as a source of power in the most exhaustive manner. Seven hundred experiments were made with different types of water wheels, and the results, published in the *Journal*, were of the greatest value to engineers. The frequency of steam boiler explosions, especially on steamboats, was a disquieting feature of the development of power engineering. The government invoked the aid of the members of the institute to pursue researches into the strength of the materials used in the construction of steam boilers. One of the by-products of this investigation was the design and construction of the mech-

anism for testing materials, a pioneer move in the direction of the Bureau of Standards which was so strongly advocated by the institute. Another and more direct step toward proper standardization was the establishment through the institute of uniform sizes of screw threads. The institute's recommendations were adopted by the Federal Government in 1865.

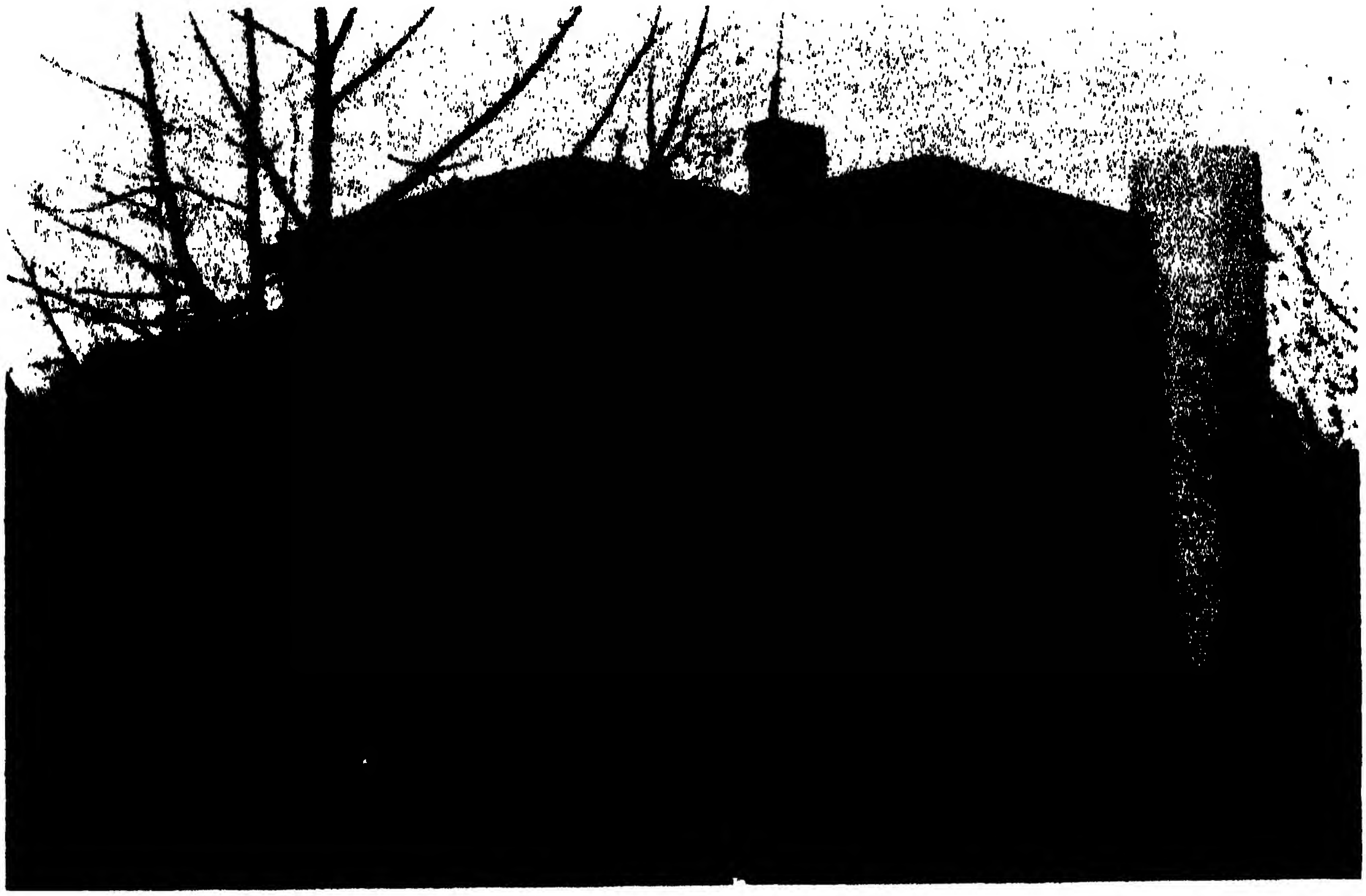
Long before the establishment of systematic weather observation by the State Weather Bureau in 1887, the institute had been laying the foundation for a better study of meteorology for the aid of agriculture. A bill which was presented to the State Legislature in 1833 relating to weights and measures was forwarded to the institute for examination and report. As a result the recommendations submitted were adopted and form the basis of the present laws on the matter.

The city of Philadelphia has made frequent reference to the experts of the institute for guidance upon many of its problems. Important studies of highway paving, protection from lightning, prevention of fires in theaters, river pollution and water supply were conducted and formed the basis for the city's manner of regulating these problems.

It is obvious from this record of service to science, industry and the community at large that the Franklin Institute was first to recognize a great many of the implications arising from the development of human progress and to suggest how technical development might be adjusted to the community's needs. As industry grew stronger and became independent of outside aid the institute withdrew from the necessity of educating the consumer to industrial advances. As the public school system grew aware of its responsibility to youth and began to bear an increasing share of the burden of education, the institute relinquished this task to the local education authorities. But it is equally obvious that such a virile organization could not surrender its activity and sink into a stage of moribundity. No sooner were its services to the community curtailed in one direction than the members sought for new means of adopting themselves to the changed conditions of life, and they cast about for the best method of supplementing the school system's instruction. The fortunate acquisition of the services of Dr. Howard McClenahan as secretary of the institute brought to its work a penetrating mind and a directional zeal that was unsurpassed. One of Dr. McClenahan's first conceptions was the creation of a dynamic museum upon a scale hitherto unattempted in this country.

Finding in the Poor Richard Club a body of men devoted to the perpetuation of Franklin's mental attitudes the happy idea was conceived of uniting their forces to those of the institute for the erection of a memorial to Franklin that would embrace all or most of his manifold integests, and to translate them into terms of contemporary life. The final achievement excelled the visions of the creators. The intention of the institute was to establish a technological museum; the Poor Richard Club wanted to erect a monument to Benjamin Franklin. Why not unite the two? Under the inspired leadership of Dr. McClenahan and that of Cyrus Curtis (the great Philadelphia publisher whose *Saturday Evening Post* descended directly from Franklin's *Pennsylvania Gazette*) a mammoth impulse was given to the movement. When subscriptions were asked it needed but twelve days to produce $5,000,000, besides innumerable contributions of material suitable for exhibition in the projected museum.

In Europe a new interpretation had been placed upon the work of the museum. The newer conception saw it as a place where the ordinary man is placed upon an equal footing with the trained student, he is admitted to the wonder-



BUILDING OF THE BARTOL RESEARCH FOUNDATION

RESEARCH IN FUNDAMENTAL PHYSICS IS CARRIED ON BY THE INSTITUTE IN THIS BUILDING AT SWARTHMORE, PA. THE WATER TOWER HAS RECENTLY BEEN ERECTED FOR THE INVESTIGATION OF THE ABSORPTION OF COSMIC RAYS CARRIED ON BY DR. W. F. G. SWANN, DIRECTOR OF THE FOUNDATION.

land of science, and becomes a free citizen in that vast territory of industrial operation whose boundaries had been closed to him by ignorance. Here the layman entered the magic world of scientific and engineering accomplishment, and through the same agency the scientist, the inventor and the manufacturer approached the community which they had to serve. The labor of man the creator was passed through the crucible of the trained mind and interpreted so that the lay mind might comprehend. The new Franklin Institute Museum bore that new conception to America and speedily translated it into reality.

The new museum achieved instant popularity. The visitors came, not to marvel, but to *use* the exhibits. Therein lay the secret to the departure from conventional museum practice. The Franklin Institute Museum was designed for utility. As the memorial to Benjamin Franklin it had to follow his type of mind. Franklin is frequently spoken of as a philosopher, but we must never picture him as a mere metaphysical speculator. He was far from that. Indeed, there is no one in the whole realm of philosophy with a more simple, practical turn of mind. "What signifies philosophy," he asked in one of his letters, "that does not apply to some use?" Therefore, utility became the keynote of this museum.

Now, the genius of the American people is mechanical rather than theoretical. For this reason its interest lies in the results of science rather than in science itself, but an abounding curiosity makes the average American keenly interested in underlying principles of science if they are brought within his grasp. Few scientific principles are comprehensible without laboratory proof requiring skilful manipulation of apparatus, delicate instruments and an ability for careful measuring beyond the lay-

man's reach. The purpose of this museum was to provide the simple citizen with a personal laboratory in which a complicated scientific theory or mechanical problem would work itself out before his eyes with uncanny precision and without special effort on his part. Special apparatus was designed to perform the functions of the experimenter by automatic impulse. All that the curious visitor has to do is to push an electric button to set the mechanism in operation.

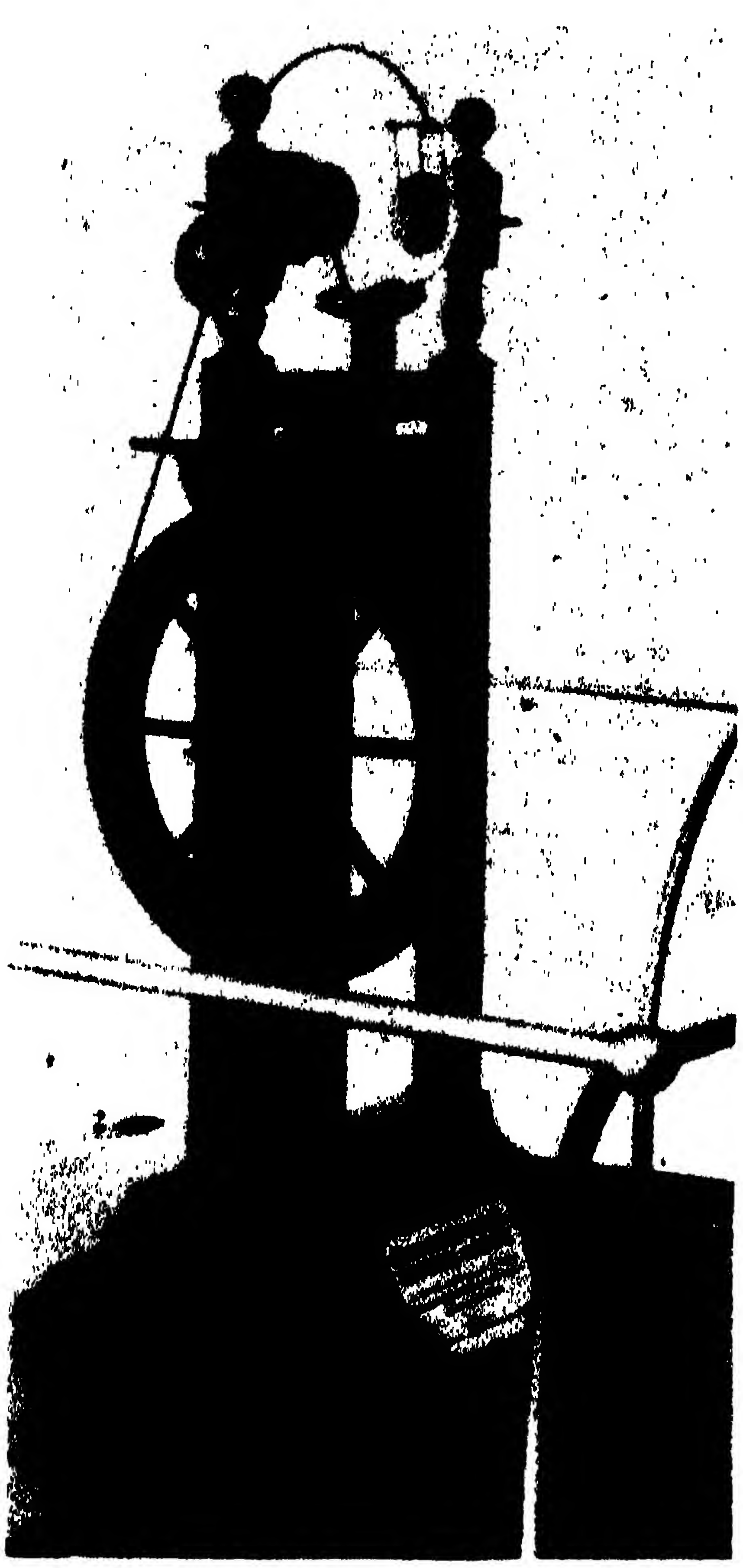
Fortunately, the institute was well served by the staff selected to design its exhibits. Dr. James Barnes in the physics section, Charles E. Bonine in the sections of engineering and transportation, Dr. Nicol H. Smith in chemistry, Russell L. Davis in the field of graphic arts, C. Townsend Ludington in aviation and James Stokley in astronomy, were all admirably qualified for translating the technical features of their subjects into automatic expression. Theirs was not merely the problem of designing apparatus. While a chemist or a physicist prides himself upon the delicacy of his experimental apparatus, that which had to be employed by thousands of visitors must, of necessity, be a sturdy and serviceable structure able to withstand abuse.

Astronomy is happily treated in two ways. On the roof of the museum is the largest and finest public observatory in the country. Two fine telescopes, a 24-inch reflecting and a 14-inch refracting instrument, are available to visitors whenever the weather is favorable for observation. Although the observatory is enriched with numerous other instruments of historical and practical aid in the study of astronomy, visitors have the opportunity of pursuing their studies in all weathers in the Fels Planetarium, where a wide variety of natural phenomena can be faithfully produced indoors. Because this wonderful instrument is capable of reproducing the skies as they are visible from any place and at any time it has been possible to take a broad view of astronomy by changing the demonstrations each month. The ingenuity of the staff has been severely taxed in designing apparatus for producing realistic illustrations of eclipses, meteors, aurora, etc., not provided by the standard instrument, but, so far, they have surmounted their problems with remarkable success.

The subject of graphic arts, because of its importance in the life of Benjamin Franklin, has naturally assumed a relatively wide appeal in its treatment. The whole subject is treated thoroughly in actual practice. Beginning with a magnificent model paper-making machine, which shows in detail the manufacture of paper, to the printing of much of the institute's requirements in this direction, and the trimming of the finished product, the visitor has full opportunity to examine the various processes and methods of printing, illustration and reproduction of the fine arts. Historically, this section is highly enriched with personal mementoes of Benjamin Franklin and a completely furnished colonial printing shop.

The chemistry section is a sheer joy to the schoolboy and the more mature visitor alike. Exhibits are marvelously designed to illustrate the fundamentals of chemical science by experiment, and to show how they are employed by the industrial chemist to give us better and cheaper products for our use and happiness. Articles of beauty rather than utility, such as glittering glass and the more delightful products of the dye bath, have been artfully introduced to make this department a place of enchantment to the visitor whose idea of chemistry is based upon the inadequate and often painful recollections of incomplete high-school studies.

Because the industrial chemical plants are performing frequent minor revolutions in our contemporary living condi-



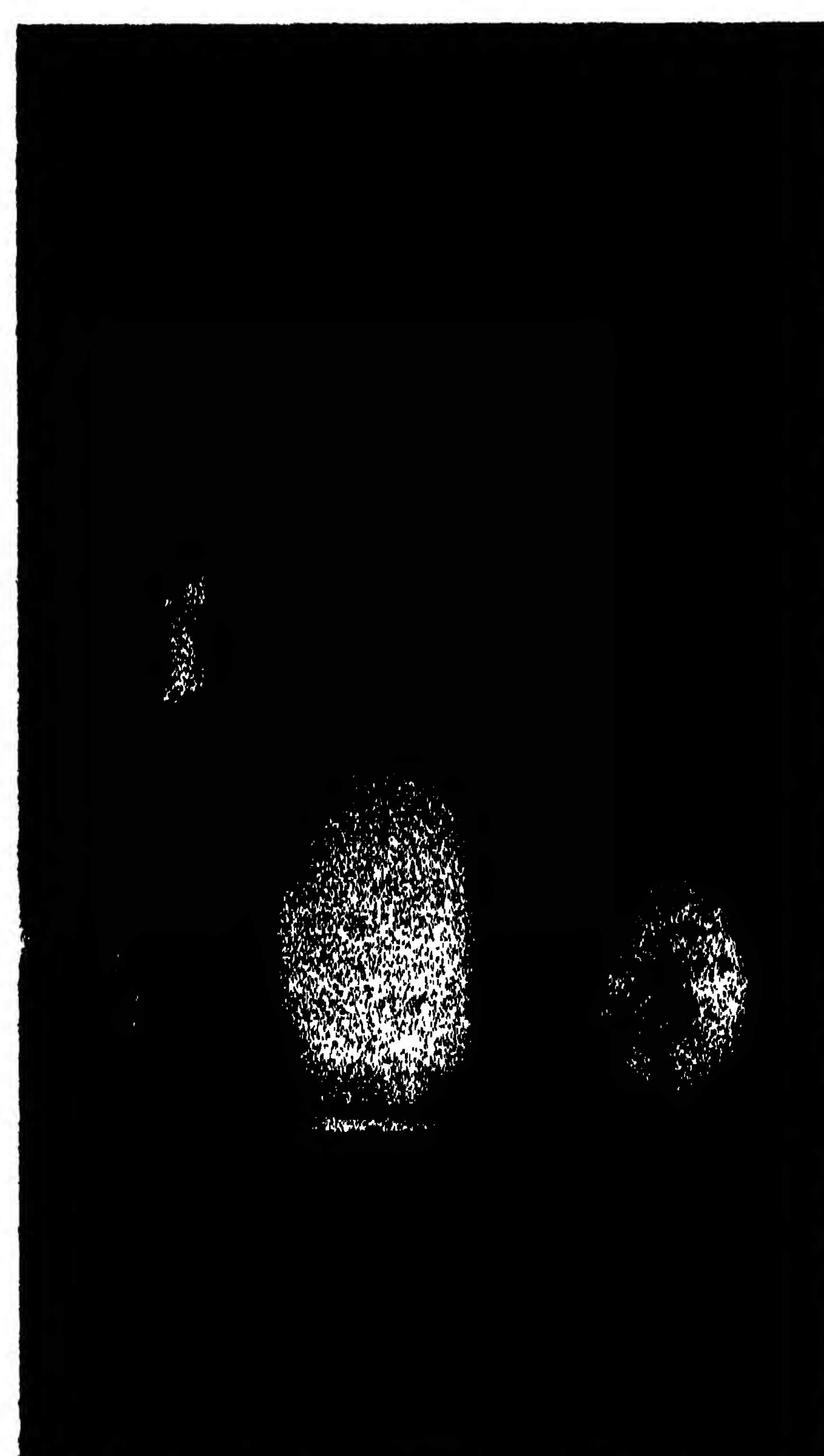
Photograph by Gladys Muller

BENJAMIN FRANKLIN'S ELECTRICAL MACHINE

THIS FAMOUS MACHINE WAS USED BY FRANKLIN IN HIS EXPERIMENTS ON ELECTRICITY, 1747–1753. IT WAS PRESENTED TO THE INSTITUTE IN OCTOBER, 1826, BY MR. J. REDMAN COXE. FROM MEASUREMENTS OF THIS MACHINE A NUMBER OF REPLICAS HAVE BEEN MADE.

tions, furnishing more stable, cheaper and enduring substitutes for natural products this section offers the best illustration of the museum's striving toward completeness. The section has its fundamental background of chemical reactions, processes and materials which remain substantially unchanged so that the visitor may have a better comprehension of the quickly changed exhibits showing the advances in industrial chemistry. Changes of exhibits in this respect are frequent and of such an elaborate nature that one sees instantly how the industrialist has recognized the intrinsic value of the museum as an agency for educating the consuming public to the advantages it derives from the transformation of substances, often of little value in themselves, into products of real value. For a large proportion of these beautiful displays, placed only on temporary exhibition in different parts of the museum, are provided by industrial firms.

Like the chemistry section that devoted to physics is concerned with providing simple demonstrations of the fundamental laws of nature. This, too, reflects a happy combination of profound knowledge and the ability to interpret it to the layman. Here is an astonish-



Photograph by Gladys Muller

COLD LIGHT EXPERIMENT

AS GIVEN BY A DEMONSTRATOR ON ONE OF THE FRANKLIN INSTITUTE'S TRAVELING SHOWS.

Photograph by Gladys Muller

PUSH BUTTON SCIENCE

A TYPICAL EXAMPLE OF THE MEANS ADOPTED FOR SHOWING DIFFICULT PROCESSES THROUGH SELF-OPERATED ACTION EXHIBITS. THIS ONE SHOWS THE RECOVERY OF CHLORINE AND CAUSTIC SODA FROM SALT. THE STORY IS TOLD BY A SPOKEN DESCRIPTION REPRODUCED BY PHONOGRAPH.

ing array of working experiments illustrating the principles underlying the vast collection of practical applications that has been assembled by several other departments.

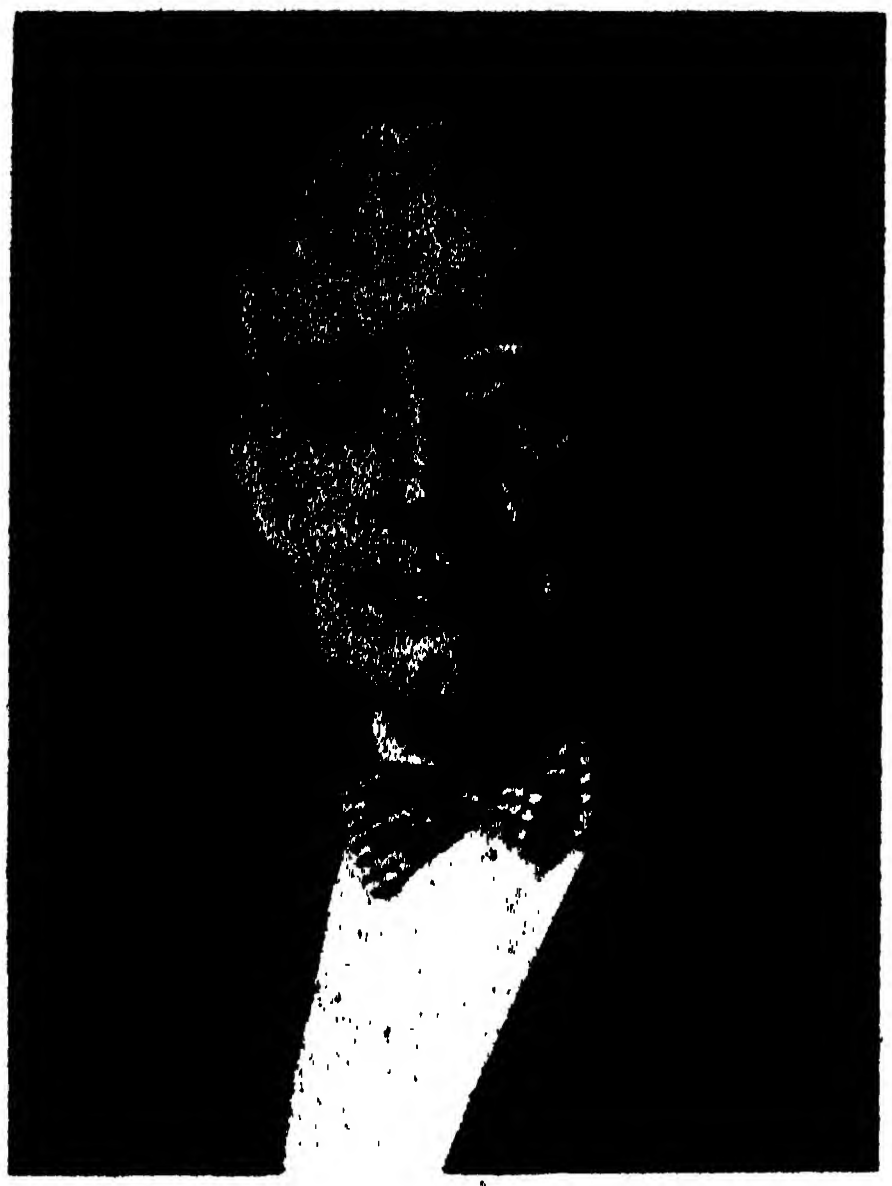
Land transportation from the Conestoga wagon to the latest model of automobile; marine transportation from John Fitch's first American steamship to the bridge of a modern liner; electrical communication by radio, telegraph and telephone; and illuminating engineering from rush-light to white light by fluorescence, show the variety of physical application brought forth by the forward sweep of civilization.

The aviation section may be quoted as illustrating the successful blend of history and modern practice which characterizes this modern form of education by museum exhibits. Here the visitor can study at leisure the theory of "lift" and resistance in a number of prepared experiments involving the use of wind-tunnels. He can turn from this theory to its application in the original applications by Orville and Wilbur Wright as shown in their thirteenth airplane; in a historic machine—that which Amelia Earhart flew across the Atlantic; in a recent example of rotating wings as employed in an auto-gyro; and, finally, he may climb into a training machine and observe in detail how the pilot controls his flight.

Startling contrasts abound. The visitor moves away from a giant locomotive (which he may actually drive!) to the smallest operating steam engine in existence; from Franklin's own friction machine to a device which enables the visitor to hear his own voice over the telephone; from examples of misspent enthusiasm devoted to the perfection of a perpetual motion machine to instruments that detect earthquakes in the far Pacific.

This new conception of a museum is one of the most dynamic forces in education, primary or adult, that the mind of man has yet conceived. It is a scientific playground with a serious object. Its ageless appeal assures its popularity exactly as wise old Benjamin Franklin himself would have wished. How that wonderful old man would have enjoyed it!

The Franklin Institute does not restrict its energies to the education of the layman or to the dissemination of ideas



HOWARD McCLENAHAN, 1872–1935

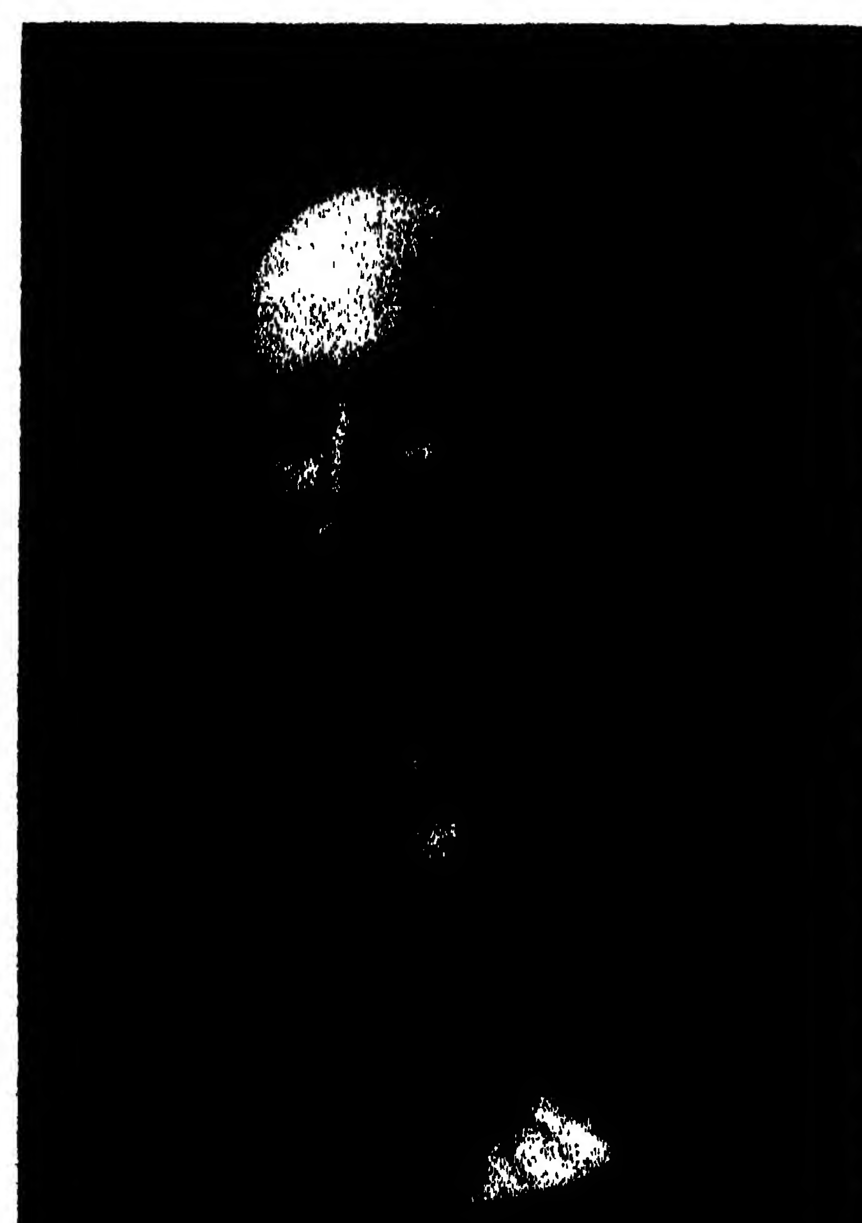
SECRETARY AND DIRECTOR OF THE FRANKLIN INSTITUTE AND EDITOR OF ITS JOURNAL UNTIL HIS DEATH. UNTIL HIS ELECTION TO THIS POSITION IN 1925, DR. McCLENAHAN WAS PROFESSOR OF PHYSICS AND DEAN OF THE COLLEGE AT PRINCETON UNIVERSITY.

through the instrumentality of its lectures. In two separate directions it engages in pure research. The Bartol Research Foundation, directed by Dr. W. F. G. Swann, and the Biochemical Research Foundation, under Dr. Ellice McDonald, are constantly making additions to knowledge, the former in physics and the latter in biochemistry.

It was a matter of more than general regret that Dr. McClenahan did not live to see the completion of his original conception, but he has been ably succeeded by Dr. Henry Butler Allen, under whose direction two important features have been brought to fruition. It was felt that, while the museum admirably answered the purpose of educating those who could come to observe its wonders, the work was incomplete until some provision had been made to reach those who were unable to pay frequent visits to Philadelphia in order to keep pace with the many changes in the museum's exhibitions.

Accordingly, Dr. Allen promoted the idea of designing traveling shows which could be carried anywhere, each performance demonstrating with the aid of numerous action exhibits certain phases of modern science. Two such traveling shows have already established the fact that the effort meets an acute want. The first deals with chemistry, and the second with aviation in a manner that delights an audience.

It is, thus, a well-rounded program that the institute has undertaken and pursued through more than a century. Its culmination as a memorial to Benjamin Franklin was recently celebrated in brilliant ceremonies extending over three days which marked the unveiling of a handsome statue of Franklin. These ceremonies were attended by scholars from all parts, come to pay tribute to America's first scientist in the



Photograph by Gladys Muller

HENRY BUTLER ALLEN

SECRETARY AND DIRECTOR OF THE FRANKLIN INSTITUTE.

name of the learned societies and colleges which had honored him in life.

America owes a lasting debt of gratitude to this man who did so many things for the advancement of mankind and more particularly for the advancement of that little group of colonies in America which gave him being and which he loved with such devotion. That debt is paid in part most effectively, we believe, and in a manner which would have gratified the creditor by the erection and maintenance of this superb museum. If Franklin could see what has been done in his name and for his memory, the kindly heart would be moved, the high sense of social duty would be satisfied, by the spectacle of well-earned wealth, neither squandered in tawdry luxury nor vainglorious show, nor scattered with the careless charity which blesses neither him that gives nor him that takes, but expended in a well-considered plan for the aid of present and future generations of those who are willing to help themselves.

INFLUENCE OF ASTRONOMY ON SCIENCE[1]

By Dr. F. R. MOULTON

PERMANENT SECRETARY, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

MANY arts and sciences have contributed to the exploration of the celestial regions. Reciprocally the heavens have illuminated and are illuminating many of the sciences that pertain to the earth, for our planet has been found to be only a particle in a universe of matter, its life only an incident in the history of the cosmos, and terrestrial phenomena and laws only particular examples of universal events and principles.

What is the foundation on which all science rests? It is what we think of as the orderliness of the universe, the regularities in the sequences of its phenomena. Without orderliness there could be no science, for unless there were a firm conviction that nature is orderly there would be no attempt to discover its order. In this age of science it is difficult to realize that in ancient times men almost universally believed that the physical universe is subject to the whims of capricious gods and goddesses. Then chaos prevailed on the earth and in the heavens above; superstitions cast their terrifying shadows over mankind. But before the dawn of recorded history regularities in such phenomena as the recurring seasons and the phases of the moon had been noted. Even before the time of Aristotle, in the fourth century B.C., the lengths of the month and the year had been measured to within a minute or two, the inclination of the plane of the earth's equator to the plane of its orbit had been determined with considerable accuracy, the causes of eclipses of the sun and of the moon had been discovered, and much progress had been made in developing theories of cycles and epicycles for explaining the apparent motions of the sun, the moon and the planets among the stars. All these great results, depending upon centuries of observations, had been established before any considerable steps had been taken in the development of the sciences that pertain only to things on the earth. It is to the glory of astronomy that in it men thus first perceived that the universe is orderly and entered on the pathway to science.

It may be surprising that order should have been first clearly perceived in phenomena presented by distant things. But distance smooths to imperceptibility the countless little ripples of phenomena which would confuse us with their complexities were we among them, and leaves

1 Address at the dedication of the Franklin Memorial, May 20, 1938.

to our perceptions only the regularly recurring great waves which roll along like the swells of the ocean. Though the moon has more than a thousand measurable cycles in its motion, a few determine all the important characteristics in the succession of its phases. In ever-changing shape, it courses through the night sky when all the distractions of the day are covered by darkness. Inaccessible and somewhat mysterious and with cycles of change short enough to be held easily in the memory, it attracts the attention and makes clear the orderly succession of its phenomena.

One of the principal methods in the development of science is generalization. If the motions of the moon are orderly, then why not the motions of those mysterious wanderers among the stars, the planets? Thus the ancients must have asked themselves the question. Since the planets revolve around the sun instead of around the earth, their apparent motions as observed from this rotating and revolving planet are enormously more complex than those of the moon. Yet long series of observations and endless calculations had led to the discovery of the order in them by the beginning of our era. All who have read the Almagest of Claudius Ptolemy, which was published about 1,800 years ago, have been amazed at his knowledge of the apparent motions of the planets and at the perfection of his theories for explaining them. In only a few other sciences have similar very close correspondences between theories and observed phenomena been reached even at the present day.

The words "order" and "orderliness" have been used as though they have perfectly definite meanings which are generally understood. But we find on examination that it is difficult if not impossible to define them and that it is equally difficult to determine whether natural phenomena are orderly according to any definition that we may adopt. It does not relieve us to say that phenomena are orderly when they obey laws that we can state, for essentially "laws of nature" are only descriptions of phenomena, often in time sequences. There is nothing of compulsion or causality in laws of nature, for they are man-made—and often man-destroyed—formulations of how certain classes of things exist or occur. Consequently, if there is any definite content in such a phase as a "law of nature" it belongs to a description, whether in words or symbols, that scientists themselves have invented.

Now what properties of a description entitle us to say that the phenomena it describes are orderly? A ready answer would be that the description is simple. But what is simple depends to a large extent upon the information and experience of the person considering it. It depends also upon the terminology or notation in which it is expressed; for example, the unperturbed motion of the earth around the sun is simple to one familiar with the properties of conic sections, but enormously complicated to one who does not have such knowledge. Or, as to notation, explicit formulas describing the complicated motions of the moon fill many pages, but the differential equations which contain implicitly everything pertaining to its motion may be written on a calling card. Simplicity of a description, therefore, does not appear to be a satisfactory criterion for determining whether the phenomena it describes are orderly, for simplicity depends in considerable part upon considerations that are entirely independent of the things described.

Another possible criterion of orderliness of phenomena is whether or not they are cyclical in character. Most of the phenomena with which we are generally familiar are approximately cyclical. Not only do day and night and the seasons endlessly recur, but there are fundamental rhythms in our own lives—the beatings of our hearts, the inhalations and exhalations of our lungs, our periods of

activity and repose, the electric potentials that rise and fall in our brains. But phenomena do not exactly repeat themselves. No day ever exactly duplicated another day, no two seasons were ever exactly alike. Although strict periodicity in nature is never found, the approximately cyclical character of phenomena appears to have been fundamental in the origin and development of science and to be fundamental for its progress. Indeed, without repetitions our memories would appear to play only with dreams and our reason would grope in vain for materials for its use. That is, the experiences which are basic in the evolution and exercise of our mental processes are cyclical in character. In general, we feel that we understand phenomena only when we analyze them into series of nearly repeating elementary events. When we have succeeded in such an analysis, we regard the phenomena as orderly, and we are satisfied.

Science was born in astronomy because many celestial phenomena are compounded of relatively few cycles. It flourished long in this science before there were comparable developments in other fields both because of the simplicity of its repetitions and because of the amazing successes of its predictions. For many centuries it alone filled the reason, as well as the imagination, with awe.

Throughout the history of science there have been attempts to discover the *causes* of phenomena instead of simply *how* phenomena occur. To account for the motions of the planets the Greeks invented crystalline spheres, apparently not realizing that if they felt impelled to ascribe causes they should explain also both the crystalline spheres and the reason for their rotation. A parallel case was the invention of the luminiferous ether to carry the transverse waves of radiant energy. These fictitious causes or instruments are in the nature of anthropomorphisms, having their origin in our feeling that by acts of our wills we cause phenomena to occur. In very ancient times men were a little more naive, inventing gods and goddesses as the causes of phenomena. Fundamentally the gods and goddesses of antiquity and the crystalline spheres and ethers of more recent times are alike. All have been introduced arbitrarily in order to make the phenomena of the physical world parallel what we regard as the consequences of our own volitions.

Now and then newly discovered facts or phenomena have compelled the abandonment of irrelevant scaffoldings in our science. Perhaps the earliest clear example was Kepler's derivation from observations of the three laws of planetary motion which he announced more than three hundred years ago. The demonstrated elliptical motions of the planets around the sun at variable angular rates made it impossible to retain as realities the fantastic crystalline spheres of the Greeks. And, similarly, the fact that radiant energy has the properties of both waves and particles eliminates the assumption of a luminiferous ether.

It is remarkable that the history of the theories of the motions of the planets has not had a greater influence on later ideas respecting the essential meaning of "laws of nature." Over and over again, even in astronomy, analogues of the crystalline spheres of the Greeks have been introduced in order to have causes of phenomena, although all we know is the relationships among the phenomena themselves.

One of the greatest and most important changes in point of view in science occurred with the acceptance of the heliocentric theory of the solar system. Although Aristarchus of Samos, three hundred years before the Christian era, clearly formulated the theory that the earth rotates and revolves around the sun, and explained by it the seasons and all the apparent motions of the heavenly

bodies, the earth was almost universally believed to be the center of the universe until the time of Copernicus near the middle of the sixteenth century. In spite of his painstaking and convincing comparisons of theory with observations, the heliocentric theory was not generally accepted even by scientists until after the time of Galileo, a century later. Then the solid earth beneath, contrary to accepted common sense, philosophy and theology, suddenly became a spinning particle flying unsupported in the immensity of space. Man found himself removed from his proud position at the center of the universe to the surface of one of its lesser constituents. As vague fears entered his heart that he might not be the principal object of creation, he naturally resented the new and subversive doctrine.

Another reason that the revolution of the earth about the sun was at first difficult to accept was that there was nothing assigned to support it or to cause it to move. This psychological defect in the theory was partly remedied by the discovery of the laws of motion and the law of gravitation, which were regarded as the cause of the motions of the planets and their satellites. Although this cause was a rather intangible set of formulae, it gradually acquired reality in the minds of scientists, as abstract ideas aldays do with increasing familiarity.

With the formulation of the laws of motion and the discovery of the law of gravitation by Newton, physical science closed a long period, extending from the prehistoric days when men first began to perceive that there is order in the motions of the heavenly bodies down through the centuries of painstaking observations to the time when Kepler laboriously worked out his three laws of planetary motion. With the publication of Newton's "Principia" in 1687, physical science entered on a new and glorious period. The transition from the old to the new was sudden, and the completeness of the revolution in point of view has perhaps never been equalled in science or in any other field of human endeavor.

Previous to the work of Newton descriptions of phenomena had been made by means of tables of values or geometrical constructions or kinematical models. All at once something entirely new was introduced, derivatives of the first and the second orders. With all the background of knowledge and experience we have now, it is difficult for us to realize the revolutionary nature of the new concepts and methods. Let us cast out from our minds Newton's work and think of the problem of describing the path of a projectile in a vacuum. From experience we know that at each instant it has a definite distance and altitude; consequently we can make a table for its coordinates. If we desire its components of velocity we can make a similar table. We can make a diagram of its path and mark off on it intervals of time. The table or the diagram is fairly descriptive of the phenomena—in few fields of science do we have more. But the equations of Newton are universal, containing implicitly complete descriptions of all properties of the motion not only at the surface of the earth but at any other place.

Dynamics originated largely in connection with the problem of explaining the motions of the moon and of the planets, though Galileo had previously gone far in his investigations of the motions of falling bodies. Fortunately the masses of the planets are so small relative to the mass of the sun that each of them moves, at least for several revolutions, almost as though the others do not exist. If it were not for this circumstance, there would not have been any simple laws of planetary motion for Kepler to discover. Without Kepler's laws, Newton could not have verified his theories of the laws of motion and of the law of gravitation. Without the work

of Newton or similar work, dynamics would not have been founded and the progress of all science would have been much slower.

Of equal importance in the founding and verifying of the principles of dynamics was the fact that the sun affects the motions of the moon, and the planets interact upon one another; for these perturbations, as they are called, are the consequences of foreign influences which would be most likely to produce unexpected results if any of the laws from which they are derived were erroneous. Newton himself made more verifications of the principles he laid down than have been made even to-day for almost any other law in the whole domain of science. His successors, particularly Lagrange, Laplace and Euler, extended the agreements between theory and observations to thousands. Some of these verifications of theory were of the most involved nature, consisting of a series of consequences, each of which in turn became the cause of other perturbations. For example, the attraction of the sun slightly increases the period of revolution of the moon, the amount depending upon the dimensions and shape of the orbit of the earth. The planets are slowly altering the shape of the orbit of the earth, with the result that the effects of the sun on the orbit of the moon also gradually are changed. Although the cycle of these slight effects are thousands of centuries in length, Laplace worked out all the complicated interactions of forces and obtained theoretical results which were precisely verified by observations.

It was not of much practical importance in everyday matters that Laplace showed that the gravitational interactions of the bodies of the solar system are in harmony, even to many decimals, with the implications of theory. But these amazing demonstrations of the exactness of the law of gravitation were made in the infancy of, or before the birth of, most of the sciences and scientific theories of the present day—a generation before Dalton's founding of the atomic theory of matter, two generations before Wöhler's first synthesis of an organic compound and Faraday's experiments on the relation between electricity and magnetism, three generations before Joule's and Mayer's formulation of the law of the conservation of energy and Darwin's work on the origin of species, more than a century before chemists and physicists first penetrated into the subatomic world or astronomers had made substantial progress in exploring our galaxy of stars. Even to this day there are no more striking illustrations than the motions of the planets and their satellites that the universe is orderly.

The indirect effects of the triumphs of celestial mechanics during the eighteenth century were the important ones. whenever in later times chemists were tempted to despair of explaining chemical processes or geologists were assuming creation and cataclysms or biologists were appealing to mysterious vital forces, there arose always before them the shining example of perfect order and comprehensibility in the motions of the heavenly bodies. Whenever scientists or philosophers were inclined to take a narrow view of the cosmos in space or in time, the limitations they were about to impose were contradicted by the immensities of the celestial spaces and the long cycles in the motions of the planets.

It is universally agreed that evolution is one of the most important concepts in science. In a sense it completes science. As has been stated, the basis on which science rests is the orderliness of the universe, and orderliness is essentially the approximately cyclical character of phenomena. But phenomena are not exactly repeated. For example, the cycles of the moon's motion do not exactly recur, nor do the waves on the sea or the

characteristics of living organisms. Evolution provides for these continual variations; indeed, it depends on them. The departures from cyclical repetitions of phenomena are not discontinuous or relatively large. They are rather in the nature of slight modifications in the cycles that we regard as essential to order. But when variations occur on the whole in one direction over long periods of time, as they may, the changes eventually become very great. So the fundamental basis of science as enlarged and enriched by the principle of evolution provides us with a universe that is orderly in a limited sense and not essentially unchanging.

Although evolution was adumbrated in the writings of the Greek philosophers, it could not take definite scientific form until recent times. It found its first clear expression in astronomy about a century before Darwin published his "Origin of Species." Curiously it appeared independently in three countries; in England in 1750, in a book by Thomas Wright; in Germany, in 1755, in a brilliant volume by Emmanuel Kant; and in France, in 1796, as a chapter in a general survey of astronomy with which Laplace followed the publication of his monumental "Mécanique Céleste." Each of these writers attempted to trace out the evolution of the solar system on the basis of the principles of mechanics.

Of the three theories of planetary evolution, that of Laplace had by far the greatest influence, partly because of the great name of its author, partly because of its relative simplicity and partly because the scientific world was gradually being prepared for such revolutionary ideas. The nebular hypothesis of Laplace, as it was called, gradually became widely accepted in science. It pointed to a long history for the earth and undoubtedly had an important influence in the struggle among geologists over Catastrophism and Uniformitarianism in the early decades of the nineteenth century. It accustomed scientists to thinking of change in long periods of time and thus prepared the way psychologically for the theory of organic evolution. It affected the philosophy of Spencer and its influence extended even to theology. By the beginning of the twentieth it had tinged the thoughts of all the world.

Since all our knowledge of celestial bodies is obtained from the radiant energy we receive from them, astronomers from the time of Galileo have been interested in the properties of light. About 1608 Jan Lippershey used the property of the refraction of light in designing spectacles. Upon hearing of this work, Galileo at once invented the refracting telescope and with it observed craters on the moon, the largest four satellites of Jupiter and spots on the sun. For different reasons each of these discoveries was of great interest and importance. But with increasing telescopic power, difficulties arose because different colors under given conditions are refracted by different amounts. To avoid these defects, telescope makers turned to the use of mirrors until John Dolland, about 1750, discovered how to correct the errors in refraction by using two pieces of glass having approximately compensating properties. Thus about a century before the invention of photography the requirements of astronomy led to the design and construction of achromatic lenses without which good photographs can not be obtained in white light.

One of the properties of light which has come to play a fundamental rôle in recent physical theories is its velocity in vacant space. The fact that light traverses interplanetary spaces with a finite, though very great, velocity was discovered by Römer, in 1675, only sixty-six years after the invention of the telescope. In this day it is difficult to appreciate the rapidity of the development of observational astronomy which led to

this discovery or the profound effect it had upon scientific thought. It does not seriously detract from its importance that the value obtained by Römer for the velocity of light was about 20 per cent. too large. The stimulating effect of the discovery that radiant energy is transmitted at a finite velocity is illustrated by the fact that Laplace attempted, but without success, to determine the velocity of gravitation.

Our familiarity with the numbers used in expressing the properties of radiant energy dulls us to the amazing realities they represent. The highest velocities with which scientists were familiar before the time of Römer were those of projectiles and of sound in the atmosphere, or of the order of a mile in five seconds. But light flashes through space at a speed equal to seven times the distance around the earth in a second. The lengths of its waves are of the order of a fifty thousandth of an inch. The number of its mysteriously transverse vibrations in a second is, in the case of yellow light, greater than the number of seconds in 18,000,000 years. These are the quantities that a world familiar only with such things as the diameter of a hair and the speed of the flight of birds were suddenly asked to accept as realities.

For more than a century astronomers lamented the fact that there is dispersion of light because it impaired the excellence of their telescopes. Then they gradually came to realize with the development and application of the spectroscope that the composite character of light and its easy separability into its different wave-lengths place within their hands an instrument of the most extraordinary value.

Let us sketch briefly the history of the development of the principles of spectrum analysis. In 1666 Newton passed sunlight through a prism and broke it up into its constituent colors, and he recombined them into white light by passing them through a similar prism in reversed position. For more than a century little progress was made in the analysis of light because all experimenters passed it through a small circular opening before it reached the prism, the images of which overlap and impair definition. Finally, in 1802, Wollaston introduced a narrow slit in place of a prism, the images of which are distinct lines. Immediately progress was rapid. By 1817 Fraunhofer had determined 324 characteristic absorption lines in the spectrum of the sun. All that remained was the formulation of the principles of spectrum analysis in order to interpret the meaning of the Fraunhofer lines and to place in the hands of astronomers a new means of investigation of the most extraordinary and unexpected importance. These principles were first approached by Ångstrom, in 1853, and by David Alter, of Freeport, Pa., in 1854; they were completed in their present form by Kirchhoff between 1859 and 1852.

And what of the results obtained by means of the spectroscope? By its use astronomers have determined the chemical constitution of the sun, its temperature, its period of rotation, the velocities of its violent eruptions, its magnetic condition, its distance from the earth, the density of its atmosphere, and have observed its prominences even when it is not eclipsed. For most scientific purposes the spectroscope has brought the sun down to the earth. It has become a physical laboratory in which the principles of spectrum analysis are verified in the flash spectrum at the time of an eclipse, in which temperatures beyond these of terrestrial laboratories are always available, and in which theories of ionization can be verified.

As applied beyond the solar system, the spectroscope enables astronomers to determine the constitution of the stars,

their temperatures, their velocities in the line of sight, often whether they are double and their periods of revolution, the masses and densities of certain of them, in some cases their periods of rotation, their distances, the existence and character of interstellar molecules and the dimensions and the period of rotation of our galaxy.

Far beyond the borders of our galaxy are other galaxies, perhaps a hundred million of them within five hundred million light years, the greatest distance that can be reached at present. By means of the spectroscope astronomers prove directly in many cases that these galaxies are rotating and also measure their velocities of rotation. From what astronomers learn about these foreign galaxies they acquire a much better understanding of our own. There is, however, one phenomenon revealed by the spectroscope in connection with exterior galaxies that was wholly unexpected and has led to the most startling conclusions. I refer to the fact that their spectral lines are displaced toward the red end of the spectrum by amounts that are directly proportional to their distances. Whether the true explanation of these displacements of spectral lines is that they are due to velocities of recession which are greater the greater the distance of the galaxy, as seems reasonable from theory and from experience in our galaxy; or whether the effects are due to gradual diminutions of the quanta of energy in the passage of light through the enormous distances of intergalactic space without changing Planck's constant, it is perhaps too early to decide. In any case, these observed phenomena are raising questions of the most fundamental character. And the applications of the spectroscope to the sun and to the stars in our own galaxy have impelled scientists to speculate on the origin of radiant energy and the condition of matter having a density, in the dwarf stars, twenty thousand times as great as that of water.

It would be inexcusable to close these remarks without referring to Michelson's attempt to measure the velocity of the earth with respect to the ether and his failure to find the expected result, for it led eventually to the theory of relativity and entirely new conceptions respecting the nature of the universe and of science. Moreover, it may be noted that nearly all the tests of the validity of the equations of relativity are astronomical in nature.

In summary, science originated in observations of the heavenly bodies, and its anthropomorphic character was successively weakened by the requirements of astronomical theories. The exterior universe has taught us much about our earth and its sciences, and much even about the workings of our own minds. The universal genius whose memory we honor to-day lived too early to know about most of the things of which I have spoken. But his daring spirit roamed thus widely through and beyond the science of his day, at one time reading the records of ancient life preserved in fossils in the rocks, at another drawing lightning from the clouds, at another finding delight in the wild flowers of the fields, at another turning his eyes and his mind to the stars. As a tribute to him I should like to paraphrase an epitaph which appears over the tomb of Newton in Westminster Abbey, where England has buried her noblest dead. In free translation it is: "Mortals, congratulate yourselves that so great a man has lived for the honor of the human race." Concerning Benjamin Franklin let us say: Americans, let us congratulate ourselves that so great a man has lived for the honor of our country.

VOLCANOES, GEYSERS AND HOT SPRINGS[1]

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ALTHOUGH volcanoes have been a subject of active inquiry for more than two hundred years and hot springs for perhaps half that time, there is an authoritative volume (Meunier, "Les Convulsions de l'Écorce terrestre") published as late as 1910, which warns us not to confuse volcanic phenomena with "pseudo-volcanic activity" (hot springs, mud volcanoes, etc.). More intensive studies of recent years, to which I invite your attention, seem to prove that all these phenomena are but phases of the same terrestrial activity. The picture may be outlined in this way.

An outbreak of volcanism obviously can occur only in a region where the fluid magma approaches much closer to the surface than in other regions. To raise the question whether structural weakness of the overlying crust or the inherent boring power of magmatic solvents is mainly responsible for the opening is quite immaterial, since both factors doubtless enter into the determination of most volcanic vents. Also whether a lava outpouring takes place along a rift, as in Iceland, or through a well-established central cone, as at Vesuvius, is a question of local physical factors and their distribution. Local temperature, composition and fluidity of the magma and the magnitude of the accumulating pressure below are factors calculated to seek out and determine the point of greatest weakness in the overlying crust. Given a very hot, highly fluid magma, such as the basalt of the Hawaiian volcanoes, and the eruption will usually consist of an explosive release of the accumulated gas pressure at the top of the lava column, followed by a more gradual escape of its volatile content and a quiet outpouring of the lava itself. In other cases where the viscosity of the magma is greater an outbreak will assume a quite different aspect, usually marked by dangerous explosive features. The chief emphasis for our consideration at the moment lies in the fact that the magma itself brings to the surface an immense source of energy which may be released under conditions determined by the amount of this energy, the chemical and physical constitution of the magma and the local resistance of the restraining crust. The fact that these magmatic sources of energy do approach the surface in this way is readily established wherever borings have been made in such regions, for the ground temperature downward rises very rapidly there as compared with other regions where no such approach occurs.

When the magma, highly charged with superheated steam and other gases, approaches close to the surface in this way it is obvious that partial release of its energy at the surface may also take place slowly by gas seepage or chemical attack upon the adjacent rocks as well as through an opening forced through a weak cover.

From this point our consideration leads us to inquire what the composition and physical character of the magma may be at these points of approach to the surface and what consequences may be expected at the surface as a result of this approach.

It is now nearly 200 years since Spallanzani observed that molten lava flowing out upon the surface did not burn on reaching the air and its liquid condition could not be due to burning sulfur or other fuel. He also appears to have been the first to suspect that the magma itself was charged with gaseous material

[1] Address at the dedication of the Franklin Memorial, May 20, 1938.

which accounted for the explosive features and for the porosity of the lava after solidification. He also intimated that its fluidity may have been due to the presence of these volatile materials and that water may have been included among them. It was also frequently noticed by the earlier observers that showers of rain often follow immediately upon volcanic outbreaks, which can be attributed to the condensation of escaping steam.

It is not my purpose to follow through the ramifications and confusion of the controversy which has continued down to the present century regarding the character of this participation of water (*i.e.*, steam) in volcanic outbreaks, a participation which appears always to have been but imperfectly understood and often flatly denied. Indeed as recently as 1911 Brun[2] published an elaborate volume containing analyses of collected volcanic products which purported to show that all volcanic emanations are anhydrous. This misunderstanding was dissipated the following year,[3] when volcanic gases were collected at Kilauea before they could be altered by contact with the air and considerable quantities of water condensed therefrom.

Out of this long controversy we may conclude that water (steam) and other gases which have since been identified are essential ingredients of the magma below ground and participate actively in all the phenomena of volcanism. It remains for us to consider what effect this may have upon the observed surface behavior of volcanoes both at rest and in action.

In the first place it may happen that as the magma approaches the surface and the overlying load diminishes, some separation and concentration of these gaseous ingredients may occur at the top of the rising column of liquid magma. It must follow from this that the solvent action of these concentrated volatiles (water and acid gases) upon the overlying structure must be considerable at these high temperatures (above 1000° C.). Such increased mobility and solvent action must find and follow lines of structural weakness in the overlying crust (faults, joint cracks) and so facilitate the continued rise of the magmatic column and determine its direction. If the stored-up energy (pressure) below is very great rupture and a violent volcanic outbreak may be expected to develop eventually, which may be limited to the partial escape of the compressed and concentrated volatiles (*e.g.*, superheated steam) at the top of a column or may include or be followed by the still highly charged liquid lava itself, as in the case of a bottle of soda water suddenly opened. Such an outbreak of magmatic energy is obviously a volcano.

But, suppose instead of this that the magmatic column approaching the surface encounters porous ground, and the accumulated volatile materials in the upper layers of the column find opportunity for escape by seepage, what then is the result? The chemically active gaseous ingredients (chlorine, fluorine, sulfur) may gradually filter away and expend themselves in reactions in the passages of the overlying rock, enlarging these and perhaps altering the composition of the rock itself, while the superheated steam will continue on until it either escapes or condenses at or near the surface. Both of these activities result in a *gradual* release of the pressure at the top of the magmatic column, perhaps to the extent of preventing an explosive rupture of the restraining crust. Such cases exist and are revealed by the chemical alteration of the rocks, by the chemical content and temperature of the surface springs and by the rapidly increasing ground temperature immediately below the surface. Where rupture

[2] "Recherches sur l'Exhalaison Volcanique," Geneva, 1911.

[3] A. L. Day and E. S. Sherpherd, "Water and Volcanic Activity," *Bull. Geol. Soc. Amer.*, 24: 573, 1913.

has occurred and a volcanic explosion takes place, there is of course abundant and readily available evidence of the activity of the volatile ingredients contained in the magma. When the eruption has subsided and the volcanic conduit is again wholly or partially closed, we must suppose that the release of pressure at the top of the column has stimulated the rise of these volatile materials from greater depths (and higher temperatures) within the liquid mass below and their escape under the ordinary action of gravity. These gases are near the surface now in a zone already perforated and may therefore readily find ways of escape by the slower processes of seepage and filtration until they encounter the cold ground water at the surface. Thereupon magmatic steam will condense, soluble gases (carbon dioxide, chlorine, etc.) will begin to enter solution in the surface water and the fixed gases (hydrogen, nitrogen) will continue on until they escape at the surface.

This ground water has its own circulation above ground, beginning with the rainfall which is distributed by surface runoff and by absorption into the surface layers and openings, and again below ground in seepage and through joint-cracks. Obviously the rainfall in the volcano region will find the ground temperature rapidly increasing as it seeps downward and its penetration will remain shallow and sharply limited wherever the boiling temperature is reached.

If we now suppose that in these regions superheated steam from the magma, more or less associated with the other gaseous products (carbon dioxide, chlorine, sulfur), to be approaching the surface from below and to encounter the surface-water circulation, certain results are immediately obvious. The superheated steam will condense, add its latent and superheat to the surface water and mix with it; other gaseous ingredients will also enter the surface water to greater or less extent, according to their quantities and solubilities, and where these circulating surface waters reappear in springs above ground we may read therein the record of what has occurred. The springs will be hot instead of cold, they will contain carbon dioxide, hydrogen sulfide, chlorine, etc., in proportions appropriate to the solubility of these gases under the prevailing conditions. Or, if the non-condensable gases are in excess, we may find them bubbling through the surface springs themselves and escaping into the air, where they may still be caught and analyzed.

Or again suppose these magmatic emanations happen to rise beneath steep hillslopes, where little or no storage of ground water is found. Then either one of two results will be in evidence: (1) very small springs highly concentrated with the acid ingredients coming from the magma, or (2) the free escape of the magmatic gases, including steam, into the air without previous condensation by ground water. In the first case there result strongly acid springs of small size and turbid, because of the acid attack upon the surrounding ground, in the second the free escape of magmatic gases into the air as roaring fumaroles or steam jets.

Thus we have brought into a single category, now abundantly supported by experimental studies in the field, both the volcano and the hot spring. If the magmatic column rising to the surface carries with it a vast amount of compressed energy the crust may be violently ruptured and an explosive outbreak of both gaseous and liquid ingredients of the magma will inevitably result. When this violent phase has subsided and the major concentration of the more volatile portion of the rising magma near the surface has been discharged, it will almost certainly be followed, throughout the perforated region, by the continuing seepage of the volatile

ingredients which may be traced through the hot springs for hundreds or thousands of years thereafter, or may be interrupted from time to time by more violent phenomena in case the main conduit becomes closed or the accumulation of energy below ground is too rapid to be satisfied by seepage release.

Thus, for example, in the North Island of New Zealand we have a perforated zone running northeast and southwest more than half way across the island. This hot-spring region is of considerable extent and includes at one end, and again near the middle, an active volcano. One of these volcanoes (White Island) rises from the sea beyond the coast line, is more or less continuously active, though only occasionally violent, and a number of hot springs and fumaroles are found there. Some of these are so highly charged with the acid emanations from the magma that the acid concentration in the springs sometimes reaches 10 per cent. It is the highest concentration of volatile magmatic elements which has hitherto been observed.

The other volcano (Tarawera) was violently active in 1886, the explosive activity tearing the mountain wide open from summit to base and opening a rift beyond the base into the hot-spring valley below which extended for a distance of nearly nine miles. Thus we have an intimate association in present time of active volcanism and hot-spring activity in the same area. It also fits in nicely with the above general outline that the hot-spring activity in the rift zone appears to be considerably diminished in volume and intensity since the explosive release of the high concentration of energy in 1886.

On the other hand, we have in the Yellowstone Park a lava plateau of much more ancient date, in which the old centers of volcanic activity are long since closed, but which still shows abundant hot-spring activity throughout its extent of nearly 60 miles north and south. An intensive study of this region, undertaken during the last seven years, has provided a number of the supporting facts in the above analysis. Borings in two different localities revealed, in the region of most abundant surface water supply, a temperature of 180° C. at 406 feet below the surface, in another region, of somewhat less abundant surface water and therefore greater concentration of the products of volcanic emanation, the temperature reached 205° C. within 246 feet of the surface. Steam pressures at the bottom of these bore-holes amounted to 57 and 297 pounds per square inch, respectively. Here also in the course of a chemical study of the hot springs it was found that in the basins, with abundant surface-water supply, the acid concentrations were found to be small, and on the hillsides, where water was much less abundant, the acid products of volcanic activity were much more highly concentrated.

In discussing the origin, behavior and chemical content of hot springs it is well to bear in mind that a hot spring differs from a cold spring not merely in the fact that it chanced to pass through hot rocks instead of cold ones in coming to the surface. If this were the case the hot springs might be expected to cool rapidly and so presently to become cold themselves, for the rocks conduct heat but poorly. Take a notable example by way of illustration. The spectacular Old Faithful geyser in Yellowstone Park erupts quite regularly, about once an hour, an estimated 10,000 to 12,000 gallons of boiling water and so brings to the surface a nearly uniform quantity of boiling water annually. It is a matter of simple arithmetic to discover that the heat necessary to maintain this intermittent hot spring would require about two square miles of red-hot rock surface, of average heat conductivity, *renewed annually*, merely to heat the water regularly distributed by this geyser. Here it is pertinent to add that none of the hot

water thrown out by Old Faithful returns down the conduit to aid in the next eruption; neither does the extreme cold of winter alter appreciably either the period of its eruptions or the amount of water which is thrown out hourly. We must also reckon with the fact that a dozen other large geysers and some hundreds of smaller hot springs share with Old Faithful the water supply of the Upper Geyser Basin in which it is located.

This leads us, I think, to an inevitable conclusion that the latent heat of more or less superheated steam coming from the magma below, seeping upward through hot ground and condensing upon contact with the circulating ground water near the surface, is the only continuing source of energy which can possibly account for the uniform and continuous supply of heat to great groups of hot springs with a record of activity in their present location, as measured by the amount of sinter deposited upon their domes, of the order of magnitude of at least 10,000 years.

In elaboration of this hypothesis it is noteworthy that in regions of deep ground-water circulation this transfer of heat occurs at greater depth and so under higher pressure and temperature than upon hillsides, where the transfer must take place near the surface where the volume of water and the amount of heat available are both smaller. It is doubtless in consequence of this that neither large hot springs nor geysers are found there.

Further proof is available that hot springs in volcanic regions are heated by condensing steam out of the original magma itself. Surface waters, which circulate by flowing over the rocks or below ground through crevices or joint-cracks, always carry in solution traces of the rock materials through which they have passed. All springs therefore bear a definite record of the kind of rock through which the water has passed because of the soluble ingredients of the rock which are carried in solution. And so it happens that the hot springs of Yellowstone Park carry variable quantities of soluble minerals from the rocks which are readily identifiable by chemical analysis. But they also carry other chemical elements not found in the adjacent rocks, such as sulfur, arsenic, boron, chlorine and fluorine, all of which are characteristic ingredients of volcanic emanations. We have therefore direct proof of the participation of the volcanic gases in hot-spring activity.

The chemical evidence thus fits perfectly into the physical picture which we have built up of the behavior of magma on approaching close to the surface, first in its effects in altering the composition of the rocks into which it intrudes, second, in supplying ingredients to the circulating surface waters (ground waters), which can be traced to no other source, and finally to provide a continuous source of energy over long periods of time for hot springs, geysers and intermittent outbreaks of volcanism.

Up to this point little mention has been made of geysers which form an integral part of our title. The reason for this lies in the fact that the geysers form but a very special case of hot springs and occur only in particular hot-spring regions where certain very exceptional physical conditions are found. In order that we may have a geyser we must have not only a continuing supply of magmatic heat from below, represented by rising superheated steam, as in the case of other hot springs, but also an abundant supply of circulating surface water in which the manner of circulation comes to have very special importance. Geysers can hardly occur without free circulation in underground channels of considerable size as opposed to the slow percolation of ordinary seepage. These channels are probably the outcome of earlier solvent action of the hot water accompanied as before by the more active chemical elements of the emanation. These channels must also

have pockets of such character and distribution that water may enter and steam pressure may accumulate faster than it can escape by seepage. Such pockets or chambers imply a fairly deep-seated circulation compared with other surface waters in the volcano region, and somewhat greater age is indicated than in the case of the more widely distributed quiet hot springs. Both of these conclusions seem to follow from the fact that they must support pressures adequate to discharge considerable columns of water often to heights of several hundred feet. This seems to imply a period of existence sufficient to provide chambers of considerable size and to seal them more or less effectively through deposition of mineral matter from the circulating water itself.

There are but three major geyser regions known in the world to-day. The largest is in the Yellowstone Park, which has already been mentioned; next to it in the number of its geysers is the North Island of New Zealand, and finally the well-known geyser region of Iceland, which, by the way, contains relatively few geysers but hot springs in thousands and several intermittently active volcanoes. The geysers of Iceland were the first to become widely known, and the word "geyser" or "geysir" comes from that country.

The Yellowstone Park in which the geyser phase appears to have reached its highest development is farthest removed in time from any active volcanism. There are glacial boulders from the last ice age scattered over some of the hot-spring formations which may indicate an age of upwards of 50,000 years. In both Iceland and New Zealand, where the number of geysers is much smaller, active volcanism is still closely associated with all the hot-spring activity. This fact may be relevant to the conclusion that time is also necessary for the development of the peculiar local formations in which geysers are built up.

The mechanism of a geyser is not fully understood even to-day, although Bunsen, as early as 1847, offered a theory of the mechanism of the Great Geyser in Iceland which has (somewhat arbitrarily) received general application and acceptance for all geysers since that time. It ought not to be forgotten that Bunsen did not offer it as a general theory of geysers, nor was the Yellowstone Park discovered at the time when Bunsen wrote. Perhaps it is not strange that it does not fit the Yellowstone geysers. Being developed from observations on a single geyser Bunsen's theory appears to-day in the light of available modern data to be precisely what Bunsen intended it to be, namely, a mechanism to account for the Great Geyser only. Its application to the other geysers of the world is not quite justifiable without appropriate adaptation. For example, the Great Geyser of Iceland in Bunsen's time erupted periodically through a large shallow bowl at the surface. With the subsidence of the eruptive feature the accumulation of cooled water in the surface bowl retreated down the tube and disappeared, presumably aiding to condense the compressed steam below and so to end the eruption. In the Yellowstone Park most of the geysers are without this catch basin at the surface and therefore do not return this cooled water to the zone of high steam pressure. According to Bunsen's mechanism, therefore, such geyser eruptions would not stop but would go on in continuous steam jets without intermittent features. It is likewise pertinent to call attention to the fact that Bunsen's theory of the mechanism of the Great Geyser provides for a strictly periodic system, *i.e.*, for eruptions at substantially equal time intervals. With the exception of Old Faithful, to which reference has already been made, few of the Yellowstone geysers exhibit even approximate uniformity in the time interval between eruptions. The Giant, for example, plays at intervals of from two to eighteen days.

Perhaps this is not the appropriate time or place for the discussion of these details, but it is surely sufficiently plain from such illustrations that the mechanism of a geyser, whether periodic or merely intermittent, is somewhat more intricate than the simple one suggested by Bunsen nearly a century ago.

It is a matter of some interest in passing that many geysers have not proved to be permanent features of hot-spring activity, even during the years of this present century when they have been under closer observation. The Excelsior, which was probably the greatest geyser to appear in the Yellowstone Park within the period of historic record, apparently destroyed its own "plumbing" by the violence of its eruptions, for rocks were frequently thrown out during eruptions and the violent intermittent explosions of the geyser, which were characteristic of the closing years of the last century, have since given way to a continuous flow of hot water. The Imperial Geyser, also in the Yellowstone Park, had a similar, though much shorter, history (about 18 months). Waimangu Geyser, in New Zealand, which probably threw water to a greater height (over 1,000 feet) than any other geyser known to us, appears to have ended a three-year period of geyser activity in 1905, and to-day not even a hot spring marks its former location. These are exceptional cases and hardly prove anything more than that too great a concentration of power sometimes leads to the rupture of the sealed chambers and tubes which are necessary to such regulated discharge. As has been stated above, the deposition of silica sinter (geyserite) about some of the geyser openings indicates continuous activity in the same spot for upwards of 10,000 years at the slow rate at which such deposition occurs. Castle, Grotto, White Dome and Old Faithful geysers in Yellowstone Park are illustrations of this.

It is also true that new geysers sometimes appear in these geyser regions and others long dormant return to activity after years of complete subsidence. The New Zealand field contains several notable examples of these long pauses in geyser history (Waikite, Pohutu).

Such a presentation of the volcano-hot-spring problem can provide but the briefest sort of summary of the long campaign of field and laboratory studies extending over more than twenty-five years in time and into several different countries, but it is hoped that the evidence here brought together is sufficiently pertinent and convincing to leave no reasonable doubt that volcanoes and hot springs have a common source of energy, namely, the magma approaching the surface and cooling there, and that the most active agents both in volcanic outbreaks and in hot springs are the more volatile components of the magma which seek to escape as it approaches the surface, and whose subsequent behavior is determined by their composition, by the total energy available, the temperature and the local conditions encountered.

HUMAN HEREDITY AND MODERN GENETICS[1]

By Professor T. H. MORGAN

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WHEN I received an invitation to speak on this occasion for the biologists, I was puzzled at first why it was I who was chosen until a friend called my attention to an anecdote told by Franklin:

> Some Madeira wine, that had been bottled in Virginia, had been sent to England. At the opening of one of the bottles three drowned

[1] Address at the dedication of the Franklin Memorial, May 20, 1938.

flies fell out into the first glass that was filled. Having heard it remarked that drowned flies were capable of being revived by the rays of the sun, I proposed making the experiment on these; they were therefore exposed to the sun upon a sieve which had been employed to strain them out of the wine. In less than three hours two of them began by degrees to recover life—they raised themselves upon their legs, wiped their eyes with their forefeet, beat and brushed their wings with their hind feet, and soon after began to fly, finding themselves in Old England without knowing how they came there.

Then, it became clear to me that it was my own interest in flies that suggested to some one that I might be able to explain the resurrection of Franklin's prodigies.

There are several explanations of Franklin's anecdote that have occurred to me—and possibly one that has suggested itself to all of you—But why spoil a good story by explaining it?

Any discussion of human heredity must emphasize the fact that man has a dual form of inheritance, one of which is peculiar to him and absent in all other animals. He inherits not only the physical attributes of his kind, but also, in a different way, the traditions of the race to which he belongs. The child learns partly by imitation, partly by instruction and individual experience, and with the beginning of speech and the invention of writing and printing the inherited racial traditions have come to play an all-important rôle in the later evolution of mankind.

The question then arises whether the habits that have been individually acquired by imitation or training will be impressed on the brain of each individual to become later a part of his physical or shall I say his biological inheritance. This is a very old problem that began with the Greek philosophers. Four hundred years before Christ, the father of medicine, Hippocrates, advocated the view that each part of the body added its contribution to the male element of procreation and thereby transmitted not only the racial characteristics of the male parent but also any additional individual characters acquired by the parent during life. This is the first historical record we have of the theory of the inheritance of acquired characters. Democritus, who lived at about the same time, held a similar view. It is not improbable that such views were widely disseminated in the folklore of still more ancient peoples.

A hundred years later Aristotle discussed the problem pro and con, and on the whole rejected the view that each part of the body contributes something that goes into the make-up of the germinal material, but he seems nevertheless to have accepted the doctrine of the transmission of acquired characters in a more subtle way.

This doctrine persisted throughout the long period between 400 B.C. and 1800, *i.e.*, for 2,200 years, as Zirkle has recently emphasized. It was generally accepted even by the church fathers, and was again brought to the notice of the modern world by the well-known French biologist, Lamarck, in 1806. Later it became a cardinal point in Charles Darwin's theories of evolution, whose hypothesis of pangenesis restated the ancient doctrine of Hippocrates. However, both Lamarck and Darwin made use of the theory in an entirely new way. They both tried to explain on its principles the procedure by which animals become adapted to their environments, and, as a result, they attempted to explain how evolution has taken place.

Seventy years after Lamarck, August Weismann (as had Kant before him) challenged the doctrine of the inheritance of acquired characters in his famous theory of the continuity of the germ plasm. In substance Weismann's theory postulates that the germ cells alone transmit the racial characters and that the germ cells are neither produced by the body cells nor are they affected by the experiences of the individual. Weismann's view is generally accepted to-day.

There still remains the question as to what extent man's physical inheritance lies behind his ability to take advantage of the traditional inheritance of the group to which he belongs, and also by his inventiveness to extend his acquired knowledge into new fields.

To put the matter crudely: is the mind of the baby a *tabula rasa*—a blank slate on which its racial traditions are to be written; or are there black, white and yellow slates (and perhaps even pink ones)?

The answer is clear. If forefathers had themselves better brains at birth than the average there is a good chance that at least some of the children or descendants may have as good brains. This means that there may be black, white and yellow brains in the sense that one kind may be more inventive or more receptive to one kind of training, and another kind to another kind of training. These qualitative differences may be small, but if they exist at the start the accumulated result of training may be very great.

This leaves out of account the possibility of the occurrence of greatly superior brains, which, so far as we know, may be only the result of happy combinations of all that is best in the race plus favorable opportunities for development; or, such superior brains may be due to the appearance of new types that transcend the original limits. We have no decisive answer to-day, but there is no reason to suppose that the physical evolution of man has come to an end; unless his physical evolution may be retarded or even suppressed by practices arising from his inherited social systems.

May I now turn to more technical problems in the general field of heredity, where the increase in our knowledge since 1900 has been extraordinary, and then consider the problem as to how far we are justified in applying the same principles to the physical education inheritance of man.

The most outstanding discovery is that of Gregor Mendel in 1865. He formulated two fundamental laws of heredity, the outcome of ten years' work on garden peas. Later the same laws have been found to apply to all other plants and to animals, including man. Second only in importance was the discovery of the mechanism in 1902 by which this kind of inheritance is transmitted from generation to generation. Later still, two additional fundamental laws were discovered that we call the law of linkage and the law of crossing-over. These are also consistent with the working of the same mechanism that accounts for Mendel's laws. A knowledge of these four laws and of the mechanism on which they are based makes it possible to-day to predict exactly what is to be expected when combinations of different characters are brought together by the intercrossing of individuals.

It would take far more time than that allotted to me, were I to attempt to illustrate in detail these principles of heredity; but I may first say a little about the mechanism behind these laws, and then give a few examples to show how the mechanism applies both to human inheritance and to that of other animals.

Each species of animal and plant has in every cell of the body, including the reproductive cells, a definite number of staining bodies called chromosomes. In different species the number ranges from two to over a hundred.

When the reproductive cells reach maturity the number of chromosomes is reduced to half the full number. When the egg is fertilized by a spermatozoon the full number is restored. Hence the characteristic number for each species remains constant. It will be noted that half of the full number has come from the father and half from the mother. The child inherits equally from its father and mother; at least so far as its chromosomes are concerned.

Mendel's first law, the law of segrega-

tion, is explained on the chromosome mechanism in those cases where two contrasted characters (elements) are carried each in one of the members of a pair. This is illustrated by one of Mendel's crosses between tall and short peas. Mendel's second law, the law of independent assortment, applies when two pairs of contrasted characters are carried in different pairs of chromosomes. This is illustrated by Mendel's case of a cross of yellow round and green wrinkled peas; and again by a cross between two color varieties of cattle.

It should be noted that Mendel's second law holds when the two pairs of characters involved are in different chromosome pairs. If this were the whole story there could be only as many types of inheritance as there are unlike chromosomes in each species. Something of the sort is true in general, for we know that the *elements* in a given chromosome tend to be transmitted together.

This is the law of linkage. For example: There are four pairs of chromosomes in Drosophila, and four linkage groups. All the characters in a group *tend* to be inherited together.

But it has also been found that an *orderly* interchange between the two members of homologous chromosomes takes place. This is the law of crossing-over—the breaking up of the linkage groups. A study of the behavior of the chromosomes, at the time when the chromosomes are about to be reduced to the half number, reveals the fact that such an interchange actually takes place. If a fly that has yellow wings and white eyes is crossed to a fly with gray wings and red eyes, then, in the second generation 99 per cent. of the grandchildren are like the grandparents, but 1 per cent. of the grandchildren are cross-overs with red eyes and yellow wings or white eyes and gray wings—they represent 1 per cent. of recombination of the two pairs of characters that went into the cross together.

Due to this kind of interchange it has been possible to discover the actual location of the hereditary elements in the chromosomes which has led to one of the most important developments in the history of chromosomal inheritance. The interchange involves large pieces of the chromosomes rather than individual elements. Two new linkage groups are established that are as permanent as those that preceded them. But these also are subject to interchange again at any level in a new individual in which they come to be present. The result is that in time all possible combinations of characters (elements) are brought about.

Now if crossing-over is as likely to take place at one level as at another in the chromosomes that are interchanging, it follows that the chances of crossing-over between pairs of elements will be greater the farther apart they lie in the linkage group. Conversely, the nearer they are together the less often is crossing-over expected to take place.

On this hypothetical assumption the genes can be arranged in a map. The most complete map is that of the genes of the fruit-fly Drosophila.

This procedure is not as arbitrary as it may seem, for it allows us to predict in what numerical proportion any new gene, that appears as a mutation, will be transmitted in relation to all other known genes.

And now I come to a still more recent discovery, one that, on a factual basis, explains another kind of inheritance. In this case an exchange or translocation may take place between different linkage groups or chromosomes. This discovery was made first from purely genetic evidence and has now been confirmed by a study of the chromosomes in the salivary glands of several species of flies. These glands are present in the larva. Their cells and their contained nuclei are enormously large. Also the chromosomes are large, as seen by comparing the ordinary chromosome group of the fly

with those of the salivary chromosomes, which are nearly 200 times as long.

It was known, from genetic evidence alone, as I have said, that at times a whole piece of one chromosome may become detached and reattached to another chromosome. It was also discovered that a part of one chromosome may be turned around—in reversal of the normal sequence of the genes. Nevertheless, the characters of the fly containing such a translocation or an inversion are in most cases identical with the original fly. This means that the sequence of the genes plays no important rôle in the make-up of a fly if it still retains the full complement of genes. It is true that, in some cases minor changes may be introduced by detachments and reattachments of pieces of chromosomes, but it is a far-fetched argument to assert from this that the theory of the gene is overthrown.

More detailed work has shown a point to point relation between the genes and the bands in the salivary chromosomes. This does not mean necessarily that the bands are the genes, but it shows beyond reasonable doubt that the chromosome maps, built up on the genetic theory of crossing-over (it took twenty-five years to construct these maps) find complete verification in the maps of the salivary chromosomes.

Let me now point to a few cases that illustrate the application of the four fundamental laws of genetics to man.

In man there are blue-eyed and brown-eyed individuals. The children of a mating between blue-eyed and pure brown-eyed individuals have brown eyes. If now two individuals that have had this origin marry their offspring will average 3 brown- to 1 blue-eyed individual. The chromosome mechanism is here the same as that of the garden pea. The inheritance follows Mendel's first law.

The second law may be illustrated by the human blood groups. For several years it has been known that there are four kinds of individuals with respect to the kind of agglutinogens and agglutinins that they contain and that these kinds are inherited in Mendelian fashion (three pairs of allelomorphs). More recently another pair has been found by Landsteiner and Levine that behaves as an independent pair. The combination of this latter with the former will serve to illustrate Mendel's second law.

There is at present one example at least of linkage in man. Haldane has shown that color blindness and haemophilia are characters that are linked in the sex chromosomes. The same evidence shows at least one case of crossing-over between these two pairs of linked genes.

The failure so far to discover more cases of linkage and crossing-over in man is due in part to the presence of 48 pairs of chromosomes and in part to the relatively few simple cases of inheritance in man. What is known, however, suffices to show beyond a reasonable doubt that the four laws of heredity and the mechanism of transmission are the same in man as in other animals.

There is a kind of inheritance in man known as sex-linked inheritance that illustrates beyond a question that the same sex-determining mechanism present in other animals is also present in man. This sex-determining mechanism rests on a difference in the chromosome groups of the male and the female. The female has a pair of X chromosomes; she is XX. The male has one X. Its mate is called the Y chromosome, which is practically empty so far as genes are concerned. He is XY. The ripe egg of the female has one X. There are two kinds of spermatozoa, one with an X, the other with a Y. Any X-bearing sperm fertilizing any egg produces an XX female. Any Y-bearing sperm fertilizing any egg produces an XY male.

Now if one of the X's carries a gene for a certain character, it is found that the inheritance of the character and the distribution of the sex chromosomes run parallel courses. The human pedigree

for haemophilia gives exactly this kind of sex-linked inheritance, and it is now known that the human male has an X and a Y chromosome and that the female has two X's.

Lastly I come to our star case which also brings us back to our starting point: namely, what we owe to nature and what to nurture, to use Galton's terms.

I refer to the occurrence of identical twins. Occasionally two babies are born that in their physical aspects are almost indistinguishable. Sometimes there may be three or four, and the quintuplets, of course. The resemblance lasts throughout life.

There is abundant though indirect evidence that identical twins come from one egg fertilized by one spermatozoon. Hence their physical inheritance is certainly the same. The twins furnish an opportunity to find out to what extent two identical brains will be influenced by the environment in which the training and traditions of the race will come to act on them; especially if the twins are reared apart. Studies of identical twins are now being extensively carried out, and when enough material is collected, and when better tests are found for measuring the intelligence and emotional resemblances and differences shown by such individuals we may hope to get very definite information as to what is owing to heredity and what to environment.

Some one may ask, what has all this to do with Benjamin Franklin? I think both the theory and the facts of modern genetics would have interested him profoundly, because numbers always fascinated him, and modern genetic work is based on precise numerical data. Again, I think he would also have been interested because he was attracted by mechanical devices, and the chromosomes furnish a mechanical explanation of heredity. And lastly I think he would have understood that modern genetics has an important bearing on population problems in which he showed great interest. As our theoretical knowledge of heredity increases, and as its application to the composition of human societies becomes clearer (it is already applied in animal husbandry and in agriculture on a large scale) its significance for the welfare of future society will be more widely appreciated; but the problem is, as I have pointed out, not a single one owing to the dual nature of human inheritance. If the transmission of the traditions of the race, its myths, taboos, customs and even its humanitarian weaknesses come in conflict with the laws of man's physical inheritance the former may at times delay further evolutionary advances of the kind that have brought man to his present status. And, on the other hand, the physical deterioration of the race, that may take place under the abnormal conditions of a complex and protected social life, can be prevented or ameliorated only by an intelligent understanding as to how such physical impairment takes place. The two sides of the problem of human heredity will constitute the future field of human engineering.

IT'S CALLED ELECTRICITY[1]

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It seems regrettable that a man who has spent half a century in close contact with electrical experiments should have to confess ignorance as to just what electricity is!

I have even been told by competent friends that I ought not ask what it is! And yet, I reflect, having in some way

[1] Address at the dedication of the Franklin Memorial, May 21, 1938.

collected a knowledge as to what water is, what copper is and even what faith is, why need I remain so ignorant when it comes to such a common thing as electricity?

I consult history and learn that for centuries of unaltered view-point, electricity was known as a spirit, and because spiritual affinities and human affections were obviously correlated, magnetic powders were prescribed by physicians to increase the attractiveness of unattractive people.

It was not till the days of our own Benjamin Franklin that electricity became one or two kinds of fluid. Fluids seem a little more tangible than spirits, and electricity became quite tangible with Franklin. By simply touching a container he could tell whether or not it was charged with electricity. But with more refined criteria, the fluid idea had to be given up. Electricity acts more like a gas in some cases. Later the gas idea too was inadequate.

The only safe way with electricity is to expect a new picture whenever new tools for better measurement are discovered.

In choosing the title I was guided first by my admiration for Franklin. I am happy in the thought that he was not seriously troubled, as I have been, by not knowing the "why and wherefore" or the quintessence of the things that his experiments taught him. The important point is: he applied what he learned. In many fields he was a most interested and inquisitive investigator, and no one ever enjoyed his occupation more. He simplified observations by pictures, as we do, but, having learned what regularly followed experiment, he encouraged his mind to bring the consequences not only within the range of expectancy but also of utility. This led him, as he wished, into continued productivity. There was no cluttering of his mind with metaphysics or a futile search for primal essences.

I feel sure he read and liked Francis Bacon because Bacon too sought utility so energetically. While Franklin enjoyed his theory of fluid electricity exactly as we do our own pictures of intangibles, he enjoyed no less the experiment through which he materialized the lightning rod.

A more useful reason for my address is interest in youngsters and a feeling that they may be worried, as I have been, by quite harmless scientific bugaboos. I would like to encourage boys to realize the flexibility of electricity. Fortunately, it is difficult to draw a perfect picture of any inside mechanism of nature. Electricity is no exception. Every one who has tried it has had his picture well painted over by later artists. On the other hand, the results of even the simplest experiments remain unaltered, and so constitute the permanent assets. This doesn't mean that pictures are useless. They are valuable catalyzers and are enjoyable. I'd like to encourage and embolden the inquisitiveness of youth. I don't wish to be didactic, but I'd suggest that we are limited in our conceptions by the inadequacy of our words and so can not express the infinite complexity of reality. It is this want which sends our imagination out in search of ideas not yet wordable. This natural, beneficial provision is a wonderful tool, but not an end in itself. Even imperfection of our old words is a boon to science. For example, the moment some one suggests that gases are just a hustling crowd of anything whatever, some interested scientist applies his individual conceptions of "hustling," "crowd" or of "anything whatever" to see if they fit the picture. and then he tries an experiment and learns a new fact. It may be futile to express any essence in words, but it is distinctly useful to try it. Words have in them plenty of inherited characteristics, and, even if perfect for past events, they seldom quite fit the unlim-

ited, novel phenomena of nature. This explains the painfully gradual growth of our scientific vocabulary.

I look on Bacon and Franklin as men who saw the need of gregariousness (I'd even say happy garrulousness) in science. New phenomena which occur constantly must be appreciated, described, perpetuated and used. This means gathering and getting together in more ways than one. So Bacon, about 1600, publicly advised the banding of scientific men to cooperate in research, "For the real and legitimate goal of the Sciences (as Bacon expressed it) is the endowment of human life with new inventions and riches."

Clearly as a consequence of his tireless advocacy, a practical proposal for an institution of experiment was published in England shortly after Bacon's death, and in 1645 well-known scientists modestly undertook inquisitive cooperation, as he had suggested. This group, which developed into the Royal Society of Great Britain in 1661, has been usefully quizzing the unknown ever since.

Thus I connect to the efforts of Bacon that proposal of Franklin's published in 1743 which led to the establishment of the American Philosophical Society. In fact, we read in Franklin's proposal "that a correspondence already begun by some interested members, shall be kept up by this Society with The Royal Society of London," and he offered to act as the first secretary.

I quote also from a letter of Franklin's written 40 years later to Sir Joseph Banks, president of the Royal Society: "Furnished as all Europe now is, with academies of science, with nice instruments and the spirit of experiment, the progress of human knowledge will be rapid and discoveries made of which we at present have no conception. I begin to be almost sorry I was born so soon, since I can not have the happiness of knowing what will be known 100 years hence."

This is not an explanatory review of electricity but an attempt to encourage further questioning and experiment, particularly by youth because the elders are preoccupied. We should let our imaginations work and forget the critics of ideas. In 1747 Franklin wrote to members of the Royal Society explaining his new view of the identity of lightning with electricity—a view that came from his experiments. One of the members of the society read Franklin's conclusions before that august society and reported that "it was laughed at by the connoisseurs." But ten years later the members were glad to elect Franklin to membership.

I am not so much interested in impressing you with Franklin's view of the static electricity in cats' fur and of Jove's thunderbolts, however, as I am in pointing out that his vivid imagination, freely expressed, put lightning rods on buildings. And they are there yet. From noticing the peculiar effectiveness of his knuckle in discharging Leyden jars, his ideas soared into the clouds, so to speak. So he broadcast his new idea, saying, "May not the knowledge of this power of points be of use to mankind in preserving houses, churches, ships, etc., from the stroke of lightning?" Most of us are more conservative and fearful than that. This was no exceptional case with Franklin. His mental flexibility included balloons, and 150 years ago he received the world's first air-mail letter after a balloon carried it across the English channel.

At this point, since I have in mind following some of the lines along which appreciation of electricity has taken place, regardless of electrical quintessences, I confess with Franklin that: "I find a frank acknowledgement of one's ignorance is not only the easiest way to get rid of a difficulty, but the likeliest way to obtain information; and therefore I practice it and think it an honest policy."

I want to be exact in dealing with electricity, but also imaginative, in order to encourage myself and others. Concep-

tions of electricity will continually change by expanding, as they have always done. Indeed, expansion is a most marked property of electricity. Even the smallest trace of it, an electron, may exert influence anywhere. The motion of a speck of electricity in San Francisco is felt in New York, whether it goes by wire or wireless.

Some time ago I reflected that if electricity is anything tangible or like a liquid, it should be possible to put some of it onto a rubber balloon, and, by having the same kind on two balloons, show the repellent forces of similar charges and the attraction of unlike electricities.

I connected two metal plates, charged respectively positive and negative, to a source of 200,000 volts d.c. After making repeated contacts between the plates and the balloons, I was satisfied that balloons could never be charged that way. But I explained my difficulties to Dr. Coolidge, and in a short time he succeeded. He charged the balloons by rubbing them on his hair. Thereafter, but not before, I could easily explain this solution by visualizing conducting films of moisture put onto the otherwise dry balloon from the hair which in turn conducted so-called frictional electricity over the surface. The balloon experiment illustrates a simple, unexpected and encouraging use of the head. The ancient experiment seemed a sort of clincher for the assumption that, whatever electricity really is, there are two and only two kinds, equal and opposite. Franklin called them positive and negative. But negative electricity sometimes acts much more positively than does positive. A radio tube would be quite a different thing if this were not the case. Attempts have been made to represent all the facts by accepting one kind of electricity only. I have always wished that could be arranged. Electricity would then be but one thing. Ordinary so-called neutral matter might be arrangements of that thing, electricity, with or without anything else. The absence of the thing from matter would leave us something new, or, possibly, nothing at all.

One of the beautiful things about electricity is that experiments forever show new and unexpected things. Before the discovery that the smallest bit of electricity is a negative electron, the professor, explaining a carbon arc lamp at school, had different ideas. A very highly magnified image of the arc left us with the impression that the current across the gap between the arc-terminals consisted of positively charged particles. Later I once tried to prove this by measuring the loss of weight of different kinds of arc-terminals. These losses were enormously influenced by position in space, because electrode-burning also took place. If any positive carbon crossed the arc gap, I failed to prove it. Experiments were tried using inert gases and vacuum. There one electrode often lost weight while another gained. But this was apparently due to simple sublimation.

I passed electricity across gaps between gold, platinum and other electrodes and even submerged them in water, hoping to eliminate effects of temperature-difference and combustion. But the results were very erratic, and I could determine no electrical migration of matter through any arc. Such simple experiments are always interesting, and the results themselves remain true. Freshly painted pictures of what goes on—that is, our imaginative conceptions—are important because they lead us to look still further and see better. We visualize now that what goes on in arcs is very complex. From the neutral vapors in the arc-path and from electrons of the cathode are derived various ions, metastable and excited atoms. These latter, in returning to electrical stability, send out radio energy in definite wave-lengths, and their wireless messages constitute the colored lights, spectra of the chemical elements.

Passage of electricity through arcs

differs considerably from the passage of electricity through solutions. Like ferry-boats, suspended particles of most substances carry electricity across a water-gap. This resembles what occurs with many but not all dissolved substances. Such migration is seen, for example, in the motion of the blue color of dissolved copper in electrolysis. Here the atomic ferry-boats are parts of salts or so-called polar bodies. Dissolved sugar, for example, does not do this, but salt does. This seems simple compared with arc-phenomena.

In case of solutions, the generation of electrical energy by batteries, which historically preceded the electro-magnetic method, fits present views of the structure, nature, tangibility, etc., of the thing called electricity, and lets us distinguish between it and its effects. Most present chemical elements, being differing collections of electricity, are stable enough to persist alone, but are often capable of reaching greater stability by mutual reaction. What one element has in excess, another may relatively lack. Under this condition they may send the difference in electricity through a solution. In a Daniell cell, we say that copper comes out and zinc goes into, solution, because of their different atomic appetites for electricity. This difference can be measured as energy between the outside connections. We picture the current flowing in the wire as negative electrons regardless of the distribution between the positive and negative flow through the solution.

I am not trying to impress you with facts but with the pleasure of speculation about them.

For utility we ought to encourage our instinctive interpretations, even though we know that the pictures can not endure unaltered. Fortunately we ourselves are sums of different experiences, so picturing natural phenomena is always a new, personal, subconscious integration. The logic may be very extensive, complex, but, fortunately, it is always individually different. Value is measured by works, and individual contributions may either be firm stepping-stones to better things or perhaps only very useful negations.

Guessing, if you will, is not as much encouraged in youth as I wish it were. I myself cramp and cripple my imagination from habit. When we review a subject like electricity, we find that some one has had carefully to make and test all conceivable guesses, good and bad. Some one digressed with his pure imagination far enough to establish new and useful things, like Franklin's lightning-rod, Faraday's electromagnetic generator or Marconi's wireless.

In 1889 Professor Trowbridge published his book, "What Is Electricity?" He wrote, "This wonderful something we call electricity circulating around coils of covered wire, makes an iron core a magnet," and, elsewhere in the same book, "Is it not possible, therefore, by enormously increasing the frequency of electrical oscillations, to drive them completely off metallic conductors and compel them to be propagated through the ether of space?" That's wireless.

It is this kind of hesitant divination that I enjoy finding in the minds of men. I think some useful people unconsciously, some intentionally, cultivate it, while satisfied and fearful folk deprecate it.

A sealed letter deposited by Faraday with the British Royal Society over a century ago was recently opened. It was sealed and preserved because Faraday wanted the world finally to know that a new view had come to him first, before there was any way to demonstrate it. Faraday had been led to the view that electromagnetic action progresses through space, and, he says, "requires time for its transmission." He even added, "I am inclined to think that the vibratory theory will apply to these phenomena as it does to sound, and, most probably, to light." (We still discuss corpuscular and wave theories of light.) It was not until

thirty-three years after Faraday secretly recorded his thought that Maxwell showed mathematically that electromagnet waves should propagate with the velocity of light. Twenty-two years later Hertz confirmed this conclusion by his striking experiments and it was still nine years later (1896) when Marconi made the whole useful. It is interesting to know that Faraday had that particular vision. But it is important to see that Franklin, Faraday, Maxwell and Marconi were all visionary and practical.

While electricity was once purely spiritual and later less mobile though more liquid, it has in our day taken on still more unanticipated forms. Nowadays all chemical elements differ only in the quantity and arrangement of positive and negative electricity. All compounds are slightly rearranged combinations of what the component atoms possess. Only to a slight extent can we add more electricity to a substance than it normally contains and even then the excess slowly leaks away.

In text-books everything is simple. They usually say, "Atoms are collections of a number of electrons and another part called the Nucleus." Or "electrons are little bits of electricity, always negative," and "they each weigh one eighteen hundredth of the H atom." "They are the fundamental and indivisible units of electricity," etc. I subscribe to such views because they keep us going and guessing. They illustrate pragmatism and are as good as true when they become useful.

Imagine the experiments which can be performed when we feel that "the relative ease with which electrons are lost or gained is one of the most characteristic of all chemical properties."

This, we say, explained chemical electricity. Moreover, all material reactions depend upon it. But so does the permanency and composition of everything, even the countless possible new elements which we make now for the first time, new radioactive matter and isotopes. We imagine that an infinite number of different elements were created at the beginning and all but our 92 mixtures disappeared. They may be replaced. If a few, like radium, attest to the soundness of this view, may we not in some way reproduce or even produce many other elements which will live at least sufficiently long to satisfy some unsuspected future needs? Such speculations, since they lead to experiments, continue a valuable mental process, whatever other product results.

The process of leaking electricity, evidenced in vacuum tubes, opened a very great field in which radio is now the significant part. The expelling force of heat on electricity introduced the new term "thermionic emission." This, we say, explained that old Edison current between the legs of the filament of his lamp. There are plenty more exact expressions of the thing electricity than I am trying to give. I need only say that such new terms as "emission," "grid control," etc., become materialized as in radio tubes long before we can explain electricity. Thus our useful vocabulary grows more complex while we seek to simplify the subject.

We think now that every one knows the electron. It is the indivisible atom of electricity. I hoped it would stay simple. But experts say that it must be regarded as complex, and one adds, "We can not hope to know what electricity is until much more is learned about the electron's structure." Getting at the internal structure of electrons will doubtless proceed, for we appreciate the growing architecture of atoms and nuclei. It will be interesting, disturbing and useful. Thus experience teaches: The more we learn about our ignorance, the larger and more useful it becomes. Electricty is less likely to be confined by our limited concepts the more we know about it, but we may always continue to find new uses for

it. It was simpler as a spirit, but it is more diffuse as it is.

For the present we adhere to the electron as the simplest and smallest bit of electricity. It was wonderful how orderly orbits of these electrons around an imaginary positive center accounted for all the different kinds of atoms. It was marvelous how shiftings of those rotating electrons accounted for the mysterious lines of visible spectra. Then too into this positive center or nucleus were imagined those significant numbers of electrons which determine atomic numbers and the periodic order of the elements. These electron ideas were all valuable steps in chemical understanding. Such disclosures open the way to entirely unexpected experiments which in turn help actually to analyze and synthesize new matter. Thus through even wild speculation, good experimental work is forcefully extended.

Even as an all-pervading spirit, one might expect electricity to come out of a spot made too hot for it, but only those familiar with bees in spring or farmers could have expected electricity to come out when cold light falls on the hive. Photoelectric cells, whose action is due to electron emission from illuminated chemical elements, are already a commercial utility and speak for the sense and versatility of negative electricity.

Even in this general and superficial talk on electricity, it would seem remiss not to do more with the interesting views now being advanced on the composition of the nucleus of atoms—the heart of matter. At this point all matter was naturally looked at as simply electricity, whatever that is. Fortunately, the process of speculative analysis never has to stop, and such unexpected things as a negative charge firmly neutralized by an equal quantity of positive in a hydrogen nucleus is given the name of neutron.

This naturally followed the studies on the electrons. I can not possibly reproduce the pictures of the whole interior of the nucleus, but I can indicate the growing complexity of what was recently entirely an imaginary and indescribable center of electron orbits. Its evident electrical nature now forces experimenters into new territory which every one may later appreciate. The inconceivably tiny nucleus which was first only a positive charge later became very definite mixtures of positive and negative charges, and then mixtures of protons and neutrons. This once simple nucleus is now becoming more and more complex, but always better understood. It is being shot to pieces through electrical bombardments by alpha particles, deuterons, neutrons, gamma rays, etc. In these processes local electrical voltages up to 20,000,000 or more are being recognized just as we speak of billion volt forces in cosmic rays. Such transcendental potentials might have been visualized before, perhaps in lightning, but if the new views of nuclei did nothing but force us to experiment with electricity of such high intensities, they would be ultimately warranted.

Cosmic rays ought to be explained before electricity, for in one way cosmic rays are simple. They cause charged electricity to discharge. A metal point, reminding us of Franklin's pointed lightning-rods, is kept electrified to such an extent that it discharges, or leaks, in irregular shots. Many things may perform this trigger action, but when all such known influences were eliminated, there was still an irregular, uncontrollable shooting out of electricity from the point, and the cause was called the cosmic ray. Experiments above the atmosphere and under earth and water show that the cosmic ray comes from outer space and that it penetrates matter very much more readily than it should if it were an electrical monitor of any known kind. Such things keep good research men avid for new ideas. Scientists want to do something about it, and part of the results are always useful as though our engendered wonderment were not warrant enough.

We were taught that action at a dis-

tance is impossible. Something in space had to handle the energy. One reads the following about electricity: "The energy in the magnetizing coil disappears from the exciting circuit and reappears in the induction circuit. It must have existed during the time of its disappearance and reappearance, in the intervening space." Such published observations produced the imaginary ether. Still more visionary adepts of science get along without it, and so promising experiments are multiplied.

Having once worked in a chair factory, where belts connected every machine to shafts which were obviously driven by the big belt of a powerful Corliss engine, I naturally still look for belts. I realize that imaginary belts called lines of force are simplifications and have replaced leather in most factories.

But I never cease marvelling at the apparently empty but powerful space between the rotor and stator of electric generators and motors. I realize that all the power is in some way shifted from the remote coils to the busy shaft, and yet I can see nothing in the space. I know that my charged balloons may repel or attract one another, and that this would take place whether the electricity is at rest or moving. We remain satisfied until we meet some experience not permitted by our picture. It is then that mental wiggling becomes interesting and application becomes valuable.

Confined to post-factual words, our imagination remains cramped and we are slow in inventing new language to cover what we can not express by previous vocabulary. This is all right, too, because when we invent the new word, we try to express within it the need actually felt for it. By this token, atom, electron, ether and lines of force have a place in our rapidly changing vocabulary and represent a great deal of concentrated and promising ignorance. Justification for all this complication is to be found in the resulting works. Attempts to relegate ether to the place where spirits go lead to fresh imaginings, these to experiments and those to service.

I do not attempt to envelop completely all electricity and its utilities, but I wonder if one can know what it really is without covering everything connected with it.

A new steel mill, making automobile sheets, now rolls hot ingots continuously into thin strips 8 feet wide and hundreds of feet long. The maximum delivery speed of the hot mill is about that of a good trotting horse. The mill operates by electricity. Several thousand motors consume the 20,000 kw. of the plant. Both direct and alternating currents are used, and voltages of 2,300, 600, 440 and 250 seem necessary. Perhaps a complete definition of electricity would include all this kind of data.

Part of this thing we call electricity might be simple. If there is any simple electrical thing, it must be the permanent magnet. Think how long we have known it! But the picture, view, hypothesis or essence of magnetism seems as indeterminate as all electricity. The most powerful magnets are now made of a mixture of iron, nickel, aluminum and cobalt and are much better than steel magnets. I don't see why. We might picture some essence in the property called metallic; but the lodestone, which is no longer metallic but consumed, is also a permanent magnet. So after trying all the hunches on mixtures of metals, any one might imagine a different and still better magnet made from oxides. One man who felt that way, and was unusually visionary, has produced some first-class new oxide magnets. The important thing is, he speculated when he learned some facts. Then he tried his experiments. In general, one can safely say about electricity that there never was so much room for new views and utility, because it never before presented so much of both known and unknown.

You see I am not even trying to explain what electricity is. I'd rather show how rapidly, extensively and intimately it changes, always defying limitations. When it comes to knowing all about it, we have hardly made the start.

One of the earliest electrical investigations was Galvani's research on the nerve of the frog leg, and electrical conduction by nerves has long been an intriguing study. The phenomena are not always simple, but are capable of increased comprehension. The conducting nerve of the frog leg was found to carry electricity by test similar to those applied to conducting wires, and now the radio receiving test is being applied to brain and nerve energy. The fields for further experiment and useful application are unlimited.

I can not leave electricity without referring to at least one of its biological implications. Here, too, my idea is to show how little we yet know and how the interesting unknown grows with new views or imagination. In our radio sets a suitable antenna picks up from space electrical influences called waves, which are reinforced, come from the electrical loud speakers as waves of air in imitation of the noises or music actually made at some distant place. This phenomenon is so common that we forget its physical beauty. But in recent biological experiments it has been possible to pick up close to and yet from the human head electrical waves which are amplified into sounds and recorded as waves on paper. That is the Berger rhythm. This discovery resulted from new views on nervous systems, including the brain, all of which apparently operate electrically. Therefore the motion of electrons of cerebral metabolism may not differ essentially from those of other radio sending stations.

No one can safely predict the outcome of studies in electricity when they involve our bodies, nervous systems and brains. Electricity is, perhaps, like us, various, and yet the sum of all the parts, and certain to be forever growing. The growth will always be due to the inquisitive mixture of imagination and experiment and is in the hands of the young.

ENGINEERING AND HEALTH[1]

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Health is one of the most precious of human possessions, and serious illness one of life's most heartrending trials. It is not so much one's own ailments that are heartrending—many people bear pain and incapacitation with astounding fortitude and even cheerfulness—but to see a loved one fighting pneumonia or infantile paralysis, crippled by arthritis, wracked by the agony of a heart attack, or bravely enduring the slow gnawing of cancer, and be powerless to do more than stand by and wait, is almost the most distressing of human experiences. Even when there is every hope of ultimate recovery it is hard to be patient; the restless urge to be doing something is almost overwhelming.

Perhaps it is for this reason that generous-minded men and women are so easily persuaded to make liberal gifts to hospitals, to medical schools and to institutes for medical research. Doubtless it was this sort of keen sympathy for human suffering that led Benjamin Franklin to promote, in 1751, the founding of the Pennsylvania Hospital, to write on lead poisoning, to conjecture as to "the cause of the heat of the blood in health, and of the cold and hot fits of some fevers,"

[1] Address at the dedication of the Franklin Memorial, May 21, 1938.

to be concerned about "what is called catching cold," about a cure for cancer and about inoculation for smallpox, to have, in short, such varied interests in the field of medicine as to be elected to membership in the Royal Medical Society of Paris and in the Medical Society of London.

But Franklin was a many-sided man, and we also find him inventing lightning rods, promoting the paving and better cleaning of city streets, discussing the draft in chimneys and the construction of smokeless fireplaces, inventing the Franklin stove or "Pennsylvania fireplace," and, forty years later, describing "a new stove for burning pit coal, and consuming all its smoke," a series of activities that would now be called engineering. May they not, perhaps, have had as potent an influence in promoting the health and physical well-being of his contemporaries as did his hospital?

To modernize the question, to what extent can the engineer be thought of as rivaling the physician in the promotion of health? In appraising this friendly competition, let us not forget that while the engineer's achievements are never so dramatic, spectacular or individualized as is the saving of a life or the restoration of a sufferer to vigorous effectiveness, the engineer deals, not with individuals, as do most physicians, but with the great masses of men, women and children that constitute modern communities. If, then, the intensity factor of his health work is, perhaps, less than that of the physician, its quantity factor is, in general, immeasurably greater. Many more people have used one of Franklin's Pennsylvania fireplaces than ever went to his hospital. And since any appraisal of the effectiveness of any sort of work, in physics or in life, depends on the magnitude of a product containing both an intensity and a quantity factor, and since the intensity factors of the various engineering activities that promote health will, I believe, be found to be far greater than that zero which alone could nullify the significant product, it is, perhaps, not unreasonable to suggest that the engineers of to-day are contributing quite as much to the promotion of health as are the physicians. I say this without any thought of minimizing the magnificent achievements of the medical profession, but merely in the hope that the mention of some commonly overlooked aspects of the work of engineers may bring to them an even greater measure of public understanding and appreciation than they now enjoy.

The virtue of Franklin's lightning rod is that it prevents disaster. A similar service is rendered by modern flood control methods, which often involve engineering works of tremendous magnitude, by the lighthouse service, by the ice patrol in the North Atlantic, by the use of radio on ships at sea, by the intricate interlocking switches, signals and automatic train-control systems on railroads, by the air-beacons, lighted fields, radio beams, blind flying instruments and radio telephones of modern transport flying, and by all the devices and slogans that are making the work of the modern safety engineer so surprisingly effective. If a penny saved is a penny earned, so too is a disabling accident avoided the equivalent of a medical triumph.

Engineers have also done much to help the physician do his work by developing and fabricating for him many useful and even indispensable instruments, such as the x-ray machine, the electro-cardiograph, many devices for electrical and thermal therapy, many intricate optical instruments from the microscope to the cystoscope and all the devices that make a modern operating room, and even a modern doctor's office, such a striking example of twentieth century mechanization. Furthermore, the radio of the engineer has brought to many a disabled seaman medical diagnosis and directions for treatment that formerly would have been wholly unavailable. The contribu-

tion to the effectiveness of health services, the world over, made by the daily broadcasts directed by the Singapore Bureau of the League of Nations is very great. The radium of the physician is extracted from its ore by engineers. In all these ways engineers are helping doctors to do their work more effectively, and thus contributing to the maintenance and promotion of health.

The most obvious, because the most direct, contributions of engineers to the promotion of health lie, of course, in the field of sanitation. By bringing abundant supplies of pure water into towns and cities, a boon that only those who have lived or traveled in arid regions can fully appreciate, by building sewers and sewage disposal plants, by modern methods of refuse-collection and disposal, by the invention and fabrication of modern plumbing fixtures, which make cleanliness easy, and by carrying forward the work that Franklin initiated on the elimination of smoke, engineers have undoubtedly saved many lives and relieved the world of much suffering. And while the medical men have had to lead the way in attacking such diseases as hook-worm, malaria and yellow fever, it has been the sanitary work of engineers that has put this hard-won knowledge into practical effect on a large scale over considerable areas. Indeed in the whole field of public health work and of preventive medicine in which so many forward-looking physicians are actively engaged, engineers are their indispensable allies. The tremendous influence which these various sanitary and other advances have had on the general health level of the population as compared with what prevailed in Franklin's time is too striking for further comment.

In the important matter of diet also, the work of the engineer has been of importance. By the development of tinplate and of intricate machines for fashioning it, he has made possible the canning of food on a tremendous scale, thus broadening and enriching the diet of the nation, and making available at all seasons, and in the most out-of-the-way places, foods rich in vitamins and hormones. The development by engineers of refrigeration on ships, on trains, in cold storage warehouses and in the home, including the newest methods of quick freezing, has contributed to the same end. Irrigation, often involving engineering projects of enormous magnitude, has helped the farmer to produce food in greater abundance and often of finer quality. Still more fundamentally, the ships and trains themselves and the motor-trucks, all invented, developed and fabricated by engineers, are the means by which most of the food of the nation is brought to those who consume it. Without them no modern urban population could exist. By these means engineers have profoundly affected the dietary habits of whole nations and have made possible the elimination of deficiency diseases and of the lowered resistance to infection that malnutrition causes.

In the matter of housing, also, engineers have played their part. They have improved the materials and methods of construction and therefore both the availability and the usefulness of buildings of every sort. They have flooded houses, offices and workshops with eye-saving light. They have transformed Franklin's Pennsylvania fireplace into a central heating plant that provides a uniform controllable temperature throughout a house. Air conditioning is just around the corner. And by developing transportation they have enabled an urban population to find over a far-flung area more healthful living conditions than were available even to the well-to-do of, let us say, the London that Franklin went to in 1757.

In all these ways engineers have contributed directly to the maintenance and improvement of the health of vast numbers of people. This is, however, by no

means the whole story. There are certain other activities of engineers that are, perhaps, not so commonly recognized as having a bearing on the health-level of a nation.

Consider, first, all that is involved in what is called a national standard of living. Technical achievements in sanitation, in the production, transportation and preservation of food and in housing may determine what is available to those who can afford to have what they want; but it is the national standard of living that determines what the average man actually gets. If the national standard of living is low, there will be bad housing, bad sanitation, mal-nutrition, a prevalence of deficiency diseases and a general lowering of resistance to infection and of recuperative power that will be responsible for much sickness and many deaths. By far the most effective way of raising the general health level of any population is to raise its standard of living. This problem is, fundamentally, not medical but economic.

But the standard of living of a community is nothing else than its production of goods and services per capita per year. Unfortunately this is not always the same as a community's capacity to produce per capita per year. At the moment, for instance, we apparently do not know how to make our economic system function in such a way as to permit men to make and consume all they could easily make and would like to consume.

But in the long run the actual production of a community per capita per year will be determined by its capacity to produce, and its capacity to produce will be conditioned largely by the possible production per man-hour of expended labor. In other words, in the long run, the only way to raise the standard of living of any community, and with it the general level of the health of that community, is to increase what a man can do in an hour by giving him more inanimate slaves in the form of horse-power and kilowatts, by giving him more and better tools and machines to work with, by mechanizing and automatizing more of the routine operations in his productive processes, by working out technological advances and inventions that displace some useful thing that is hard to make by something else equally useful and easier to make, by showing him how to handle things more deftly and how to postpone or avoid fatigue, and by more effectively organizing the team-work of the industrial unit in which he works. Only by such means as these can the standard of living of any community be permanently raised. And only engineers can provide these elements in the increased hourly productivity of the workman of to-day and to-morrow. By raising our scale of living in the future, as they have marvelously raised it in the past, engineers can markedly affect the future health-level of the whole population.

Over shorter periods, a high standard of living is characteristic of what we call prosperity. Any one who ventures to talk about the business cycle is treading on dangerous ground. But it is, I think, generally admitted that a characteristic of most waves of prosperity is the rise of an important new industry. The automobile and the radio are striking examples. What the next new industry will be, no one knows. But it is surely safe to assert that, when it comes engineers will have been responsible for its genesis and growth. Only industrial activity, energized by the genius of the engineer, can generate good times. If, then, it is to engineers that we must look both for the long-term trend and for the cyclic bulges in the upward progress of our standard of living, their part in the maintenance and improvement of the health of the nation is great indeed.

All that I have said thus far pertains to the *physical* health and well-being of mankind. But our friends the physicians know even better than the rest of us the importance of that other aspect of men's

lives that may be called *mental* health. Always important in itself, it often influences, if it does not completely dominate, physical condition.

Here particularly we can look to him whom we honor to-day for an almost perfect example of this important human quality. Franklin was indeed, to quote Mr. Julian P. Boyd, "a man unacquainted with inhibitions and repressions and spiritual malaise"; "he accepted the world as given with imperturbable serenity"; he "took it all easily, relishing it, savoring it, without rest and without haste adding to his knowledge, fortifying and tempering his intelligence, broadening his point of view, humanizing and mellowing his tolerant acceptance of men and things." I know of no better description of mental health. Nor do I know of any better prescription for living happily, as Franklin did, to the age of eighty-four years.

But how, you may well ask, can engineers contribute to the wide-spread diffusion of such mental health as this? It is, of course, too much to hope that large numbers can ever be brought to anything like the perfection of sanity, poise and serenity of Benjamin Franklin; but to bring any considerable number of men and women even a little nearer to perfect mental health would be an important achievement. This, I think, engineers can help to accomplish in at least two ways.

The first depends on the fact that a considerable proportion of men and women spend more than a third of their waking hours on an industrial job of some sort. Some one has said that the chief difference between a professional man and a job holder is that the former lives through his work, the latter by means of it. I see no reason why this cynical characterization of industrial work should be accepted as inescapably true or why such work can not be made to afford to the worker an acceptable and satisfying way of living. The old-fashioned craftsman thoroughly enjoyed his work—at least many modern writers seem to think he did. And I believe that many of to-day's workers enjoy the part they play in industry. We are all too likely to ignore all the non-financial incentives and rewards of business and industry.

But enjoying one's work is greatly enhanced by, if it is not actually dependent on, having a job that one can do well. This is where the engineers come in. They are beginning to feel their way into new fields of management which involve both adjusting jobs to their holders and assigning men to the right jobs.

Adjusting a job to its holder may be done by a machine designer or by a motion-study specialist. Many modern machines are designed with special reference to the convenience and comfort of those who are to operate them; though how much remains to be done is indicated by the saying of one of my friends that there is only one machine in the world that is perfectly adapted to the operator, and it took three thousand years to do that—the machine in question being the axe-handle. And to the extent that motion-study is used to make jobs easier and less fatiguing, rather than merely to speed up production, it can confer great benefits on the worker.

Assigning men and women to the right jobs holds even greater promise of materially raising the general level of mental health of the working population. Industrial managers are beginning to make notable progress in studying human beings objectively, in measuring individual differences, in appraising both the strengths and the weaknesses of prospective employees, in cataloguing the pattern of strengths and weaknesses most appropriate to each particular job and in assigning men and women to the right jobs. I could tell you, if time permitted, of men who came into an industrial testing laboratory restless and inefficient, sometimes even morose and uncooperative, because

they had strong aptitudes of certain kinds on which their jobs made no demands whatever, and how, in many cases, reassignment of these men to jobs that called into play all their aptitudes resulted within a year in almost miraculous alterations in personality and outlook on life. I could tell you of women, trained at their own request as comptometer operators, who became nervous wrecks within a year because of the lack of a certain necessary aptitude which could easily have been detected in advance. Nor should we forget the intangible but often important stimulation to personality that comes from the mere fact that one has been studied and measured, that one's abilities have been sought out and recognized, that one's life has been paid attention to and discussed as an individual adventure. Not that the millennium is immediately at hand by any means—the engineer-managers of to-day have only just begun to scratch the surface of this highly promising field—and he who tries to go too fast in it will come a cropper, and perhaps temporarily discredit the whole field. Nevertheless I am convinced that this kind of activity will produce, in the next twenty-five years, a greater harvest of human satisfaction and mental health than any of us can yet conceive of.

Turning now to the second way in which engineers can hope to help bring more abundant mental health to the world, we find ourselves facing a much more difficult problem. Perhaps I am over-optimistic in even mentioning it as one that engineers or any one else can hope to solve. And yet, in its various ramifications, it is probably the most important problem that civilization faces today. I refer to the problem of industrial instability, the problem of the recurrent recessions and depressions that periodically throw millions out of work and disrupt, sometimes permanently, the lives of many of them, the problem of social insecurity.

That social insecurity can profoundly affect the mental and even the physical health of great numbers of people is indubitable. Worry has wrecked more lives than tuberculosis has. And there is no worry so insistent as that which besets a self-respecting industrial worker and his whole family, if he thinks there is danger of losing his job, except that of the worker who has lost his job. I suspect that this sort of worry is by far the most important single factor in the American health situation to-day.

What hope is there of lightening this incubus of fear caused by industrial insecurity? What hope is there of steady, perhaps even of guaranteed employment?

Two types of thinking are current with respect to problems of this sort, one political, in the best sense of that word, the other industrial. It is characteristic of the political type of thinking, whenever a social problem can be defined at all, to attempt to solve it by enacting a law. This type of thinking holds, consciously or instinctively, that social progress can best be forced forward by legislation. This dogma, to those who are persuaded of its validity, is comforting. It affords them an opportunity to do something about it, here and now, without waiting for the slow processes of social evolution. In some cases reform by means of legislation is indeed the only practicable procedure, particularly when a recalcitrant fringe of unsocial competitors has to be whipped into line with the standards which a great majority would be glad to maintain if they could. But to coerce a majority to proceed faster along the path of social progress than they are ready to go is a process both difficult and dangerous, even though alluring. In such a case, education is more to the point than legislation.

The political type of approach to the problems of to-day may, of course, succeed in remaking our world, particularly if it be reinforced by plenty of emotion-stirring propaganda. It may even lead

to the most effective forms of government that the world has yet seen. These new forms of government are, however, almost certain to be highly centralized, closely integrated forms of government, exerting over industry and over the lives of citizens generally the detailed regulation and control which seem to be essential to making any planned economy work. Personally, even if I were sure that the political approach would lead to highly efficient governmental forms and to really well-ordered lives, I would rather sacrifice some of this efficiency and orderliness to secure more individual initiative and responsibility, more of a chance for each of us to make his own mistakes and enjoy his own triumphs.

The industrial type of thinking about economic and social problems proceeds in quite a different way. Too often in the past, unfortunately, it has tended to ignore such problems altogether as long as possible and, when at last they loomed up inescapably, to try to fight them instead of to solve them. But the industrial leaders of to-day are beginning to have an economic and sociological background with which to think through the remoter human implications of the decisions they make and the policies they pursue. They are beginning to work out, step by step, each in his own business unit, some sort of social justice with respect to the conditions and rewards of industrial work and the effect of it on the whole lives of workers. The industrial type of thinking pins its faith to the hope that all these tiny steps forward, scattered all over the country and through many industries, influencing each the other both by the contagion of example and by the educational process of thoughtful discussion, will integrate into a march of progress that, however halting and irregular it may at times appear to be, will have firm ground under its feet.

The key to the whole economic and social situation, according to this way of thinking, is the breeding of a sufficient supply of industrial administrators who have not only sound business judgment but also enough social understanding and vision to better adjust the functioning of our present economic and industrial system to the welfare of society at large. Many of us are hoping that such progress will be made rapidly enough to forestall the motivation for and the possibility of too much legislative experimentation.

But, you say, where do engineers come into this picture? The answer is that more and more are engineering-trained men finding themselves in positions of executive responsibility in business and industry. There seems to be something about the training and experience of engineers that fits them for such work. Instinctively they deal with facts rather than with traditions and emotional reactions. Their work forces them to see things in the large, to fit details into long-range plans, to see visions and dream dreams and then translate them into reality by the careful organization of a multitude of various contributing activities. I believe that engineering-trained men are destined to contribute far more than their proportionate share of the industrial leaders of the next quarter century. If so, they are facing a great opportunity and a great responsibility. If they can learn to think around their jobs as well as thinking their jobs through, if from their natural vantage point as liaison officers between capital and labor they can get a comprehensive vision of the aims and aspirations and points of view and prejudices of both groups, if from their familiarity with the flow of materials through a factory or the flow of energy through a power plant they can derive a vivid picture of the flow of goods and of money through the channels of production and consumption, if their experience in handling men on the job can bring to them some understanding of how men want to live, they can, perhaps, contribute more than any other single group

to the solution of those fundamental economic and social problems of which we have been speaking. And if by these means they can, even to a small extent, diminish the worries inherent in industrial insecurity, they will have made the greatest contribution of the century to the promotion of the mental health of vast numbers of people.

May I then suggest that he who is profoundly interested in maintaining and improving the health of mankind and who has enough vision and imagination to sense the long-time trends of life, would do well to devote a considerable part of his energy or of his beneficence to fostering engineering education and research. In particular he should be interested, not only in the technical aspects of the profession, but especially in those branches of it which are concerned with industrial management and with the foundations on which sagacious industrial administration must rest. The results will not be so easy to observe, so directly and immediately obvious, as if he had been instrumental in training a succession of wise physicians or skilful surgeons, or in conquering some obscure disease, but in the long run he will accomplish much improvement in both the physical and the mental health of his fellow men.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]
WASHINGTON, D. C.

A DISCOVERY MADE BY A TINY TELESCOPE

You rightly hear much about the giant telescopes having 100-inch and 200-inch diameter mirrors and the wonders of the heavens they show and will reveal. But it should not be overlooked, as is sometimes done, that excellent and important work is being performed with small equipment.

The discovery of the brightest stellar object ever observed—having a luminosity equal to 400,000,000 suns—which was recently announced by Professor Fritz Zwicky, of the California Institute of Technology, is a splendid example of a major discovery made with a tiny telescope.

Using a small 18-inch Schmidt type telescope, Professor Zwicky has been photographing the sky for over a year at Mt. Palomar on the site of the great future observatory which will house the still-to-be-completed 200-inch diameter telescope.

With this Schmidt astronomical camera, having an extremely wide field of view, Professor Zwicky has obtained some 600 good photographs of distant nebulae.

Three super-nova stars were found, giving complete confirmation for the previous suspicion of the existence of two types of temporary stars; novae and super-novae.

It was one of the super-novae, known as I. C. 4182, which has turned out to be the brightest stellar object ever discovered, according to calculation by Professor W. Baade, who is Professor Zwicky's colleague.

Novae are stars which may have been known for years as well-behaved members of the galaxy that suddenly flare up into flaming brilliance for a short while and then drop back into obscurity. What causes these outbursts of brilliance is one of the mysteries which astronomers ever seek to track down. Professor Zwicky's work is added additional information that brings nearer the day of clear explanation.

THE RECOVERY OF LOST RADIUM

You probably have not met a "radium hound," but he is a valuable creature, with a very scientific ability at playing "needle in the haystack" to the tune of thousands of dollars. He is in a class with divining rods. Who named him is not known, and fortunately his pointing abilities are not frequently required.

Born in the physics laboratory, the "radium hound" is not a dog but an instrument, either the electroscope or the Geiger-Muller counter, both of which are affected by the gamma radiation given off by radium.

Radium is precious stuff and when it is used in the treatment of cancer and other diseases it is sometimes lost. The amount used is so small and seemingly insignificant that patients often can not be made to realize its value. A hundred milligrams in the form of a salt occupies the space of about a quarter inch of pencil lead. In former days this small amount cost $12,000, and while the price of radium has been reduced materially a heavy investment is still necessary.

Dr. Robert B. Taft, of Charleston, S. C., has compiled amusing anecdotes and statistics on radium losses and the methods of recovery. There are 107 records

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

of losses with 59 complete and 11 partial recoveries.

In one case Dr. Taft found some radium that had been on a dump for several weeks. In another case he saved an innocent man from going to jail on circumstantial evidence of radium theft. When the radium was located with the "radium hound" instrument, he was absolved, which Dr. Taft considered worth more than the money involved.

So sensitive are the radiation counters used that whole houses can be searched for radium from the outside in cases of suspected theft. Since radium can cause dangerous burns if it remains near a person unshielded, the "radium hound" gives reassurance that lost radium is not located where it will cause harm.

The prize radium hunt, in Dr. Taft's opinion, ended in the stomach of a pig. The radium was lost in a hospital, the rubbish from which had been taken to a pig farm. This was a case of "complete recovery of radium, complete loss of pig."

DISCOVERY OF THE SWEETNESS OF SACCHARIN

Many of the older generation can remember the newspapers in 1884 and their stories of a new kind of "sugar" which was 500 times sweeter than the ordinary variety. And they may have read speculative tales, too, about the potency of the grain alcohol which could be made out of this new sugar. Actually what was reported was the discovery of the chemical saccharin, completely unrelated to sugar in a chemical sense, and without any fermentation properties.

Saccharin was discovered in the work of the graduate student, C. Fahlberg in the laboratories of the then-famous Professor Ira Remsen at Johns Hopkins University.

Two stories exist about the discovery of saccharin's sweetness which bear retelling. One runs that Professor Remsen was lecturing to his class one day with samples of many newly prepared chemicals before him on the table. During class he unconsciously poked his pencil into several samples.

Later, in his office, he puzzled over a tough problem and touched the tip of the pencil point to his lips. Its amazing sweetness sent him scurrying back to the lecture hall, where he systematically tasted all the chemicals until he found the one prepared by Fahlberg at his direction.

The other story, related by Fahlberg in Berlin in 1904 at a chemical congress, tells how he (Fahlberg) had been working all day in the laboratory. After washing his hands he went home to supper, but the bread and everything he handled tasted very sweet. He soon found that the sweetness came not from the food but from his hands and even forearms.

The rest is quite similar, with Fahlberg tasting all the chemicals he had encountered that day. Remsen and Fahlberg's original paper on the discovery of saccharin was published in 1879. Their experiments were performed just 60 years ago, in 1878. The press of 1884 was only five years late with the news.

JAPANESE PYRETHRUM MONOPOLY

The highlands of Kenya in East Africa, just south of Ethiopia, are the newest spot where attempts are being made to grow pyrethrum flowers, whose extract goes into insecticides that must be harmless to man and animal. Fly sprays are a major product using pyrethrum, although it enters into the composition of certain sprays for garden crops.

This bit of information may not set America tingling with its significance, but one can be sure that Japan is keenly aware of the African pyrethrum plantings because the little pyrethrum flowers form one of Nippon's much-prized cash crops.

Japan in fact produces about 95 per cent. of the world's pyrethrum, and the United States, using some 20,000,000 pounds a year, is half of the world market. In Japan, pyrethrum is comparable with cotton in the southern states as a cash crop.

A report in *Industrial and Engineering Chemistry* on the Kenya pyrethrum plantings and harvest shows that the little flowers of African cultivation are superior, in their potency, to the Japanese variety. While pyrethrum plants have been grown in many parts of the world—California, Lancaster, Pa., and Colorado are three American examples—it is only in Kenya that a product superior to that of Japan is obtained.

Although the United States uses large amounts of pyrethrum it is unlikely, in the near future, that it can be grown economically here in competition with foreign lands. The pyrethrum flowers are picked by hand and the cheap labor of Japan and Africa has the situation well under command.

THE DOMESTICATION OF THE AFRICAN ANTELOPE

Farmers in Africa may some day be able to harness big antelopes to their plows, and have their meat to eat and their hides to make into harness and boots. Domestication of the eland, an antelope bigger than most oxen, is suggested by Professor Caesar R. Boettger, of the University of Berlin, as a possible solution to Africa's cattle-pest problem.

The tsetse fly, Africa's most dreaded insect, is making parts of the continent uninhabitable because it carries the germs of a disease deadly to domestic cattle and other live stock of non-African origin. It deprives the natives of their chief form of wealth and makes farming impossible to white settlers.

The native fauna of Africa are not totally immune to the tsetse-borne disease, ngana, but they are highly resistant to it. They survive when ngana wipes out whole herds of domestic cattle.

The chief obstacle to be overcome in using the eland or some other member of Africa's rich population of large hoofed animals is their alleged untamability. None of them has ever been domesticated in modern times.

However, Professor Boettger believes that the difficulty lies not so much in the psychology of the animals as in that of the natives. They have just never taken the trouble to try, he thinks, and he points out the success of the Belgian efforts in the Congo, in making good work-animals out of the supposedly untamable African species of elephant.

Once in the remote history of Africa antelopes were kept in man-tended herds, Professor Boettger states. Monuments of the oldest dynasties in Egypt show herds of three antelope species kept within enclosures. Antelope-keeping became a lost art, however, long before the end of antiquity in Egypt; perhaps because imported cattle were easier to manage and more profitable.

Immediate success could not be looked for, perhaps. But, probably, our Neolithic ancestors had to work on cattle, horses and other animals for many generations before they became tractable and really worth their keep.

THE ORIGIN OF CORN

Corn has long been one of the greatest of botanical riddles. Nobody has known where it came from. Wild forms of most other grains are known, but corn has remained a botanical orphan. Not only does it lack any identified ancestors, but it has only two cousins in the Western Hemisphere: teosinte, which is a Mexican fodder plant, and a wild grass named Tripsacum.

Now come two Texas scientists, Dr. P. C. Mangelsdorf and Professor R. G. Reeves, with strong evidence that the ancestor of corn is corn—a primitive type of grain known as pod corn, in

which each grain is covered with a tiny individual husk of its own. Pod corn is unknown in the wild state, but even as a cultivated plant it has certain definitely "wild" characters.

One suggestion that has in the past had the support of some botanists, namely that teosinte is the ancestor of corn, they dispose of very neatly by adducing good genetical evidence that corn is one ancestor of teosinte, the other being the related grass Tripsacum. They hold that teosinte originated as a natural hybrid, probably when the migrating Mayas, about A.D. 600, carried corn into the natural range of Tripsacum in Mexico.

One difficulty about the wild pod corn hypothesis is that the Peruvian Indians, who without much question originated corn culture, are the only ones who do not grow pod corn at all. But, reasoned the two scientists, not unlikely the Peruvians had carried their agriculture to such an advanced stage that they discarded pod corn long ago, while less advanced Indians still used it.

So they leafed through old manuscripts, examined effigy pottery from the very earliest known Peruvian culture levels. Finally, at the Peabody Museum of Yale University, they found a faithful replica of a prehistoric ear of pod corn.

They do not feel that the wild form of corn is necessarily extinct. It may still exist, they think, in the little-explored unforested lowlands of southwestern Brazil, Bolivia or Paraguay.

THE VALUE OF LEGUMES

Legumes—lespedeza—forage crops—and a lot of other big words are meaning much to farmers these days, when soil improvement is almost as important as crops.

Legumes have the happy faculty of enriching the soil on which they grow so far as nitrogen is concerned. They take nitrogen directly from the air and manufacture it into plant food, through a partnership arrangement with bacteria that live on their roots.

Alfalfa and red clover are the commoner legumes, but the vetches, field peas and the annual lespedezas are also important.

There are others that most peoples have never heard of. The agronomists and plant breeders have them tucked away in their experimental plots, testing them, seeing what they are good for. Some of them may be the legumes of the future, plants that will allow the farmer to get crops profitably from unpromising land.

One of the most intriguing is a kind of lespedeza that does not need to be planted each year. This perennial species, *Lespedeza sericea,* comes back year after year from the crown as in alfalfa. It is still somewhat of a novelty in spite of its introduction from China before the turn of the century. Although grown commercially, it is still something to show visiting agriculturists at such places as the Tennessee Experimental Station oı Arlington Experimental Farms near Washington.

Older stands grow tall and bushy. Hay can be cut from it two or three times a year. One fault is that it contains too much tannin, the stuff used for tanning leather, to please live stock too well, but made into ensilage the tannin content is reduced so that stock eat it readily.

It produces lots of seed which is beginning to be used in poultry feeds. Better learn how to pronounce lespedeza.

THE DANGER OF LAXATIVES IN APPENDICITIS

Too many persons are dying of appendicitis, in spite of campaigns to reduce this mortality and in spite of a quite recent downward trend in the mortality. This opinion, held by many authorities, is reaffirmed in a statement from the New York State Department of Health.

Appendicitis ought to be, as Dr. Reginald Fitz of Boston points out, "a disease easily diagnosed, of no great danger, and when recognized early and submitted to proper treatment, readily amenable to cure."

Improper use of laxatives and delay in removing the inflamed appendix seem to be the chief factors that keep the appendicitis death rate up. On the laxative subject, Dr. J. O. Bower of Philadelphia is authority for the statement that between 1918 and 1935 "248,000 . . . have been literally slaughtered with laxatives."

Dr. Fitz cited figures from Peter Bent Brigham Hospital in Boston showing that of 65 patients who died of appendicitis, 74 per cent. had taken some sort of cathartic before entering the hospital, whereas of 100 patients who recovered, only 51 per cent. had taken a laxative.

The same cases also showed the effect of delay in having the appendix removed. None of the patients who died was operated on within 12 hours and only 11 per cent. within 24 hours of the onset of acute abdominal pain or bellyache. Of the patients who recovered, 8 per cent. were operated on within 12 hours and 25 per cent. within 48 hours of the onset of pain.

If the abdominal pain or bellyache lasts over four hours it is probably serious. Authoritative advice in such cases is: Call a doctor, do not eat or drink, do not take laxatives or cathartics.

Sometimes appendicitis follows a blow on the abdomen. Doctors are not agreed whether in such cases the blow was the sole cause or whether it precipitated an attack in a previously inflamed appendix. The important point is that such cases of appendicitis are unusually severe and demand immediate surgical attention.

RECREATION INTERESTS AND AGE

Church-going still leads as a leisure-time activity, if a sample of the Missouri population may be considered as typical of Americans in general.

And church-going is one of the few interests that do not fall off with increasing age, according to a survey conducted by Dr. Eugene S. Briggs, of Phillips University, Enid, Okla., and reported to *School and Society*.

Old age and increasing enforced leisure seem inevitable, unless one is to escape through death. Yet it is surprising how many of our recreational interests are those that do not appeal to the aged.

Even the movies fail to hold the elderly, those who never attend increasing steadily from 18 per cent. at 20 years to 50 per cent. at 40 years, 72 per cent. at 60 years and 100 per cent at 90 years, Dr. Briggs found.

Card playing, dancing, radio listening and even the entertaining of friends lose interest as we grow older, it seems.

Age does not affect concert or lecture attendance.

Hobbies are enjoyed by only 39 per cent. of adults, but appeal particularly to men and women between 65 and 75 years of age, 95 per cent. of whom ride a hobby. Hobbies hold the better educated and the city dweller, Dr. Briggs discovered.

Athletic sports are not participated in much by adults, even if horse shoes are included, Dr. Briggs said. Only one in ten country folks play athletic games as often as once or twice a week. Here again the interest wanes with increasing age.

Of all adults who read newspapers, 40 per cent. find recreation in so doing. A similar percentage find recreation in reading magazines.

Books are not very popular, for 60 per cent. have read no books in the past six months. And if you think that books are neglected only by those remote from libraries, you are due for a surprise. The greatest number of non-readers of books were born in the city.

CITIES AND NATIONALISM

By Professor EUGENE VAN CLEEF
THE OHIO STATE UNIVERSITY

CITIES are social organizations expressive of man's gregarious habits. They are functional indices to the cultural and economic structure of the regions of which they are a part. Cities are born, develop with varying characteristics sensitive to internal and external influences and, like the humans of which they are constituted, decline. Evidence is abundant that they are unstable. Yet, few persons are fully conscious of this fact. "The Fall of Rome" makes little impress beyond being an attractive expression connoting a more or less mystical event of the dim past and, incidentally, has a euphonious ring. The decline of Tehran, Merv, Bukhara or the disappearance of Tyre and Sidon causes no disturbance among us who to-day are far removed from the sites of these centers—far removed historically as well as physically. Even the succession of remains of recently extinct lumber towns in the Great Lakes Region or mining communities in the eastern coal fields fails to arouse concern among our confident citizenry. Yet, if it be true that instability even to the extent of threatening the very existence of a city is a reality, that fact is of such profound significance that it should excite the interest of every one. Our failure to recognize this critical aspect of the national well-being will make impossible a satisfactory adjustment of the nation to the social and economic revolution now in progress.

Cities are closely integrated with rural areas both in an economic and a physical sense. As cities expand areally, they do so at the expense of rural lands. Likewise, as their population grows, their economic pressure upon agricultural producers is increased. Thus as cities reduce the area of agricultural lands, they demand more food. Increased production may arise from more intensive cultivation of the lands in the *umland* (immediate vicinity of the city), and on lands in more remote areas or by bringing under the plow, lands not heretofore worked. Whatever the means, the fundamental premise that the reciprocal relationships between city and rural populations give rise to points of friction, clashes of interests and to various types of economic and social interdependence, calls for a careful appraisal of these two population elements which constitute the nation.

We recognize that the horizontal growth of cities is not only inevitable but is essential to the welfare of a properly planned city. As the means of communication become increasingly effective, reducing distances in terms of time from hours to minutes, suburbs and satellite cities are drawn functionally within the confines of the central city itself. Likewise, the reduction in time closes the areal gaps between cities and extends the radius of influence of each of them. Interrelations between urban and rural areas, among urban centers and even between states, become increasingly complicated. The city no longer remains a provincial entity with purely local interests, but acquires regional characteristics, and regionalism implies a certain responsibility associated with nationalism.

During the era of the New Deal, the spirit of nationalism as expressed by an increasing concentration of power in the Federal Government has grown at an alarming rate. We grant the desirability

for cities to recognize the national government as a possible harmonizing and coordinating agency. However, a people who seek to preserve freedom of action which a democracy is supposed to afford, dare not surrender its own privileges in favor of remote control by a bureaucratic régime. The theory of those in the national capital that the clash of urban and rural interests can best be alleviated by a nationalistic organization is based largely upon the supposition that agriculture is nationalistic rather than local in relation to the consumption of its yields. The theory further builds up the idea that the significance of state boundaries has disappeared owing to the nature of present-day convenient and rapid means of communication. Hence, the nation can be more effectively directed by its division into more or less natural regions responsible directly to Washington. Apparently, cities within the regions are to become subservient to a regional directorate. Submission to this plan means surrender of democracy in the cities.

A Finnish writer remarking about the urge toward self-sufficiency and centralized control in the modern state has said: "The idea of the state and the idea of the city are contrary notions." Here is a philosophy worthy to ponder over. A nation is essentially fixed in area and boundaries; a city, as we have already indicated, is flexible. It is a competitive organism which rivals other centers in the struggle toward economic and social achievement. The national state as the dominant directing force in the destinies of a city will resolve the latter into an impotent element and reduce it to the level of its weakest competitor. Nations depend upon cities for their existence; not cities upon nations. Preservation of the city as a virile, dynamic element is essential to the preservation of a strong nation.

When proud Athens and powerful Rome lost prestige, the Greek and Roman empires fell with them. When the cities within these empires ceased paying tribute (taxes) to the central government, that government collapsed, but not so the city. Cities, in fact, in early European history tended to become self-sufficient and often did attain independence. Feudalism was essentially one such form of independence. In the course of the centuries climaxed by the industrial revolution, cities arose in ever-increasing numbers and, by different means unnecessary to detail here, grouped themselves under central governments to become nations. Germany, itself, a loose confederation of states until 1871, to-day is largely a collection of cities and city-states, most of which are losing their independence. The continuing character of cities has been illustrated within the past two decades, when many European boundaries have dissolved, but the cities within them have survived. Royal Riga, formerly in Russia, thrives as the capital of Latvia; venerable Strassburg, in pre-war days a commercial center in Germany, to-day pays taxes to France; cosmopolitan Trieste, which served old Austria-Hungary, still functions as a port but under Italian rule; bold Beograd (Belgrade), once the capital of Serbia, pays homage to the government of Yugoslavia; and Wien, at the cross-roads of important central European trade routes, no doubt will continue to play a conspicuous rôle even though it has shifted from Austrian to German rule.

Agricultural experts often refer to the dependence of cities upon rural areas for population supply as one argument in favor of greater consideration for the farmer. The implication is that without the farmer there would be no city population. Hence the farm population is the be-all and end-all of our preservation as a nation. Naturally, it is futile to argue which of two reciprocal elements is the more important. However, we should

note that cities actually do not consciously import farm population in an effort to maintain themselves. O. E. Baker, a government expert in farm economics and population movements, has cited the following elements which "tend to push the young men and women off the farms": (1) the rate of natural increase of population; . . . (2) technical progress . . . ; (3) depletion of soil fertility . . . and (4) devastation of crops and livestock by pest and diseases." Of course there is always the lure of the city with its excitement, bright lights, supposed opportunities, wages in ready cash and still other seeming advantages to attract the rural folks. But the city does not grow because it wantonly entices persons from rural districts.

Most of the motivating force behind the migration of population from rural to urban habitats has originated in the rural habitat itself. City and urban areas being interlocking parts of an economic structure they can not be divorced without destroying that structure. Improved means of communication, including rail facilities, automobiles and good roads, regularly scheduled airplane services, wired telegraph, radio and motion pictures, have virtually knit rural and urban areas into a single biological unit. No longer are the peoples of these regions and their respective activities strange to each other. On the contrary, their differences grow less and less, while their similarities tend to become identical. We may well view our population composite as distributed in agglomerations made up of people who are engaged in manufacturing and distributive services (city people) on the one hand and producers of foodstuffs (farm people) on the other hand. The conflicts which seem to arise between peoples of urban and rural areas are due to a lack of appreciation of the mutuality of their respective services. Mark Jefferson has said: "What is rather carelessly called rural population is only the least nucleated part of a highly nucleated whole. . . . Rural folk awake and at work are tied up to the city in every act of life."

If, then, the city is the keystone of the nation, any attempt by the national government to serve as a paternalistic authority operating under the guise of seeking to establish equality in purchasing power and wealth for all, is certain to weaken that keystone and to cause the collapse of the entire structure. If we would not follow in the wake of European nationalism which is already challenging the individuality of cities and dulling the senses of the people, we must plan our future so as to maintain the vigor of our cities as well as that of the rural element. Such planning must proceed upon the philosophy that the city plus its continuous hinterland is the climax expression of a nation's level of civilization.

THE FORCES WHICH GOVERN THE ATOMIC NUCLEUS

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(A) Introduction

When we speak of the forces acting deep within the atom, just what do we mean? And how valid can our ideas and statements be about anything so far removed from our direct perception and experience? The extremely small dimensions of the central heavy cores or nuclei of atoms of the various chemical elements have been measured by very direct methods—by simply shooting high-speed particles (nuclei of hydrogen or helium atoms, for example) at thin films of materials and observing that hundreds of millions of these particles pass straight on through for every one that is appreciably deflected. All solid bodies are literally full of holes, because all atoms are comprised largely of empty space; they have their mass or weight almost entirely concentrated in these central nuclei, a hundred thousand times smaller than the atoms themselves. The relatively large dimensions of atoms are simply the dimensions of the atmospheres of light-weight electrons which surround the atomic nuclei. How do we know that even the *idea* of a force has any meaning in a region of space ten-million-million times smaller than our own thumbs and fingers?

The answer is of course that we simply define what we mean by force, and the question then transforms itself into asking whether the ideas of force and energy and mass and momentum, which we define in accordance with our experience with larger things, are *useful* ideas in a discussion of these small regions.

These, then, are the primary ideas. We assume that mass or inertia is a basic property of the small particles of which matter clearly appears to be built, and that mass, measured in accordance with our definitions, cannot be created or destroyed; then we inquire the extent to which these ideas, together with the familiar concept or definition of force, are useful in the sense that by using them we are enabled to predict the behavior of the atomic or sub-atomic particles under given new conditions from our observations of their behavior under other different conditions. The answer to our question, as I hope to indicate, is that force and mass are useful ideas in a discussion of atoms, in fact to a remarkable degree. We are able to organize nearly all the information we have about the inside of the atom, and about the interactions between atoms, in terms of force, mass, energy and momentum, just as these concepts serve us in the physics of things of ordinary size. I shall point out also, however, that certain puzzles most certainly still remain.

(B) The Primary Physical Forces

The main ideas to be presented in this lecture can be outlined very briefly. It will be a flattery of my powers of exposition if even three main points can be made to appear worth remembering about a subject as far removed from your own work and interests, presumably, as the forces which act inside the atomic nucleus.

One point is this: Physical science is now so comprehensive in its scope that we can describe all the interactions between material bodies in terms of just three different kinds of forces. All the welter of actions and reactions in the world of physical things, from astronomy down

through mechanics and heat and radio and light, and on down through chemistry and atomic structure and into the atomic nucleus itself, all these phenomena can be described as expressions of just three fundamental forces, namely, gravitational forces, electromagnetic forces and the forces which govern the atomic nucleus. Perhaps these three forces may ultimately be reduced to different aspects of some one great, all pervading and all-inclusive type of force, but for the present we should be satisfied to have them reduced to only three. The description of the whole universe in terms of just three kinds of forces is a truly astounding simplification of the near-chaos in which we appear to live.

A second point is that when we make our analysis fine-grained enough to deal with the atom and its parts we have to introduce two elements into our formulation which are not necessary when we deal with things or systems of ordinary size. Every one is familiar with the fact that in dealing with gravitational forces the ordinary analysis had to be modified by the introduction of the concepts of the relativity theory when the analysis was extended to extremely large dimensions. Similarly, when we go in the direction of extremely small dimensions and deal with atoms and atomic parts we find it necessary to make two modifications—we must introduce an element of discreteness or discontinuity, as indicated by the name "quantum theory," and we must take account of what is called the phenomenon of exchange, which I shall attempt to illustrate later. These two modifications grow out of our recognition of the essential limitations of our concepts of the real nature of matter—the nature of particles and the nature of waves—when we carry these ideas down to the most exaggeratedly microscopic dimensions. This is just another repetition of the old dilemma of particle-theory versus wave-theory, well illustrated by the history of theories regarding the nature of light. Newton explained light in terms of particles; the discovery of phenomena of interference a century ago required light to be wave-motion; to-day we know that there is an essential duality about light—it has both wave-characteristics and particle-characteristics. Similarly with our understanding of atoms we have a duality of particle- and wave-properties, as expressed in the modern form of the quantum-theory called the wave-mechanics.

The third point which might be remembered refers to the distinction we make when we speak of a problem or a difficulty as "fundamental." A fundamental difficulty means a trouble which is inherent in our basic concepts, the failure of the idea itself, as distinguished from a difficulty of complexity, the failure of our mathematical or experimental abilities to meet the needs of a problem. It is impossible, for example, to write down a detailed mathematical solution describing the motions of a hundred particles all interacting simultaneously with each other—even the classical three-body problem can be solved only with restrictions—but the interaction of two bodies represents no such difficulties of complexity, and if our formulas fail to describe a two-body atomic problem correctly, for instance, we know that there is trouble with our ideas or concepts themselves. It is this kind of a formulation of what we mean by a fundamental problem which has kept the emphasis of the work in our laboratory at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington so definitely concentrated on problems which are essentially simple, such as the interaction of a proton with another proton, or of a proton with a neutron. Protons and neutrons are the primary heavy particles out of which the nuclei of all atoms are built. (A proton is the nucleus of an ordinary atom of hydrogen; the neutron is a particle of the same mass but without the

positive charge of one electron which is carried by the proton.)

(C) Nuclear Physics and Magnetism

Before we proceed to a discussion of the various experiments which give us direct information about the behavior of matter inside of the atomic nucleus I might indicate the facts which led to such investigations being carried out at the Department of Terrestrial Magnetism of the Institution. Reminding you of what I have just said about the meaning of fundamental problems, the briefest way to state it is to say that our studies of the atomic nucleus and of the simplest interactions of the primary particles of matter constitute an effort to carry out the most fundamental investigations which it is possible to formulate regarding the basic nature of magnetism itself. This means finding out the laws governing the interactions of magnetic bodies or particles in the most exaggeratedly fine-grained case which we can examine. I need only remark further that at the time when the department's program in nuclear physics was inaugurated in 1926 by Dr. Breit and the author it was just being discovered, and has since been amply demonstrated, that one of the very few—three or four—known attributes of the primary particles of matter is the fact that they all possess magnetic moment or intrinsic magnetization. As far as the magnetization of the Earth is concerned one must say that such studies as these have little or no significance beyond the rather important one of a fundamental understanding of—learning the fundamental laws of—the phenomenon of magnetism with which we are concerned. The problems concerning variations of the Earth's magnetic field can now be accounted for in considerable measure, even quantitatively, especially since the results of exploring the upper atmosphere by means of radio echoes, as originated by our department in 1925, have become available. However, there is one really outstanding puzzle which all our knowledge of physics is still unable to explain, namely, the enormous permanent magnetic field of the Earth, which is about 94 per cent. of the magnetic field which acts on a compass and which is after all the thing we mean by terrestrial magnetism. We now have measured the deepest forces within the atom, we have, so to speak, chased magnetism all the way down to the smallest particles inside the atom, but we still have no clue as to why the Earth and the Sun have such large magnetic fields, each related in the same way to their directions of rotation. Perhaps some obscure atomic effect of the extremely high pressure at the centers of these large bodies may be the cause of the magnetization, but as yet we have no indication of why it comes about, and some new principle of physics may yet be required. It is more reasonable to believe, however, that the permanent magnetic field of the Earth is a problem of complexity which we as yet have no basis for calculation, rather than a problem of concept or fundamental idea. Almost certainly it will not require a revision of the well-authenticated laws of electromagnetic action, although some unexpected phenomenon, such as to constitute in effect a large electrical current inside the Earth, may ultimately be the explanation.

(D) Indirect Information Concerning Nuclear Forces

Mass defects: The hundred-year-old hypothesis of Prout, that all atoms are built up out of units essentially the same as hydrogen atoms, was placed on a firm experimental basis by the experiments of J. J. Thomson some twenty years ago, who showed that many (now most) of the chemical elements are each in turn mixtures of different species of atoms, separate species of the same chemical element, differing from each other by one unit of mass or weight. This unit is approximately the same as the mass of one hydrogen atom, although signicantly smaller.

Since the discovery of the neutron in 1932, a particle having very nearly the same mass as a hydrogen atom but with zero electrical charge and hence no attached electron to give it chemical properties, we have accepted the view that all nuclei are built up out of neutrons and protons, the proton being the nucleus of a hydrogen atom—a particle possessing an electrical charge exactly equal and opposite to that of a negative electron, and approximately 2,000 times as heavy as an electron. We may ultimately choose to consider that nuclei are built up of neutrons and positrons (positive electrons), a proton in the nucleus then being considered as dissociated into a neutron and a positron. At present this view appears to present so few possibilities of attack as to render it unripe for any theoretical formulation to be made, but it may well be true that protons lose their identity in the close confines of the nucleus. It is obvious that the problem of nuclear structure is one of inherent complexity and is correspondingly difficult to formulate, since we find that all nuclei have dimensions not very much larger than the protons and neutrons of which they are built—if we accept as the "sizes" of these particles the distances of separation at which large non-electrical forces become abruptly evident.

When protons and neutrons are bound together to form atomic nuclei an amount of energy is given off, in the form of radiation or otherwise, which is called the energy of binding, and since energy and mass are equivalent properties in accordance with special (restricted) relativity this binding-energy shows up as a loss of mass in the compound nucleus—its mass is smaller than the masses of the protons and neutrons which entered its structure by an amount which is an exact measure of the binding-energy—the energy that would have to be supplied from an outside source to again separate the nucleus into its component parts. This is called the "mass-defect," and it gives us an exact measure of the end-result, so to speak, of the actions of the nuclear forces. Mass-defects throughout the atomic table have been carefully measured, and they show one outstanding property of the nuclear forces, namely, that the energy of binding per particle is approximately constant throughout the atomic table, being roughly eight million electron-volts for each proton or neutron which enters the nuclear structure. This characteristic is referred to as "saturation" — whatever hypothetical kinds of nuclear forces we devise must therefore exhibit this property of saturation.

Nuclear transformations: A second source of information regarding the nuclear forces is the large body of data relating to nuclear transformations, or atomic transmutations ("atom smashing"), which has been built up since Rutherford's first demonstration of artificial transmutation in 1919, and especially since Cockcroft and Walton in Rutherford's laboratory first accomplished the same feat in 1932, using as bombarding particles protons which were accelerated by a high voltage applied to a vacuum tube—incidentally one of the possibilities envisioned when our department's high-voltage program was begun in 1926. The data on atomic transmutations give primarily a confirmation of the data on mass-defects. When a transmutation occurs with the evolution of energy (resulting in a loss of mass, a higher binding-energy) this energy appears frequently as kinetic energy of the resultant system of particles (one or several particles are emitted from the complex temporary system formed by the projectile and the target nucleus, leaving a residual nucleus which recoils as the particle is shot out). Measures of these large reaction-energies confirm the mass-defect data, but the measurements on nuclear transformations give one additional important kind of information. They determine the probabilities of various kinds

of reactions; they determine, so to speak, the rate of activity of the nuclear forces, and the degree of stability of various combinations or states of motion of the nuclear particles. This last remark is especially true because many of the products of reaction of nuclear transformations have only a limited stability, even though they are nuclei of the ordinary chemical elements and behave with perfect propriety in all chemical reactions. If a proton or a neutron is added to a nucleus to form a new nucleus which is one unit heavier or one unit lighter than the ordinary stable nuclei of the same chemical element as found naturally (I do not mean to imply anything "un-natural" about our alchemistic procedures), it is observed that the extra-light or extra-heavy nucleus "blows up" later. These nuclei explode in the same way as do the nuclei of the well-known radioactive elements at the heavy end of the atomic table—they possess a certain fixed probability which leads to the spontaneous emission of a negative or a positive electron during a given time. Accordingly, at the end of a period which varies from a fraction of a second to months or years, depending on the particular nuclear species, half of the unstable nuclei present at the beginning of the period have transformed themselves into a stable species of nucleus belonging to the adjacent element in the atomic table. This phenomenon is called artificial radioactivity, discovered by Irene Curie and F. Joliot in 1934[1]

High-voltage equipment and technique at the Department of Terrestrial Magnetism: Because some nuclear transformations are millions and even billions of times more probable than others the problem of unraveling the meaning of simple observations on the particles emitted by given targets under bombardment is not a simple one, since no targets are ever really chemically pure. It became clear early in our work that reliable conclusions could be obtained only by quantitative observations of the highest order, and in our first studies of artificial transmutations, from 1932 to 1935, we concentrated our attention on the development of a technique adequate to deal with the problems to be met. I shall pass over this work with the remark that the quantitative yields of various reactions vary quite differently with voltage, and accordingly the most analytical technique is one in which the voltage or energy of the bombarding particles is under accurate control and is subject to accurate measurement. This includes, of course, the requirement that the bombarding beam must be very nearly homogeneous in kind and energy.

Our high-voltage source (Fig. 1) is an old-fashioned electrostatic generator charged by a belt, a device re-invented at an opportune time (1931) by Dr. R. J. Van de Graaff, then at Princeton University (the idea of belts for conveying the charge was proposed as long ago as 1870 by Lord Kelvin and by Righi, who constructed somewhat similar machines of small size at that time.) The high-voltage electrode is simply a ball of large diameter, following the standard electrical practice of preventing corona-losses by using electrodes of suitably large dimensions and small curvature (we used similar spherical "corona-caps" in all our experiments with Tesla coils and high-voltage tubes in the years 1926 to 1930). At the top of the vertical glass vacuum-tube, inside the 6-foot ball, is a small metal tube filled with a hydrogen (or heavy hydrogen) discharge at low pressure and low voltage (supplied by a small 110-volt generator driven by an auxiliary insulating belt). Protons or deuterons or helium ions (nuclei of light or heavy hydrogen or of helium, produced as ions in the low-voltage discharge) pass through a small canal from this discharge into the high-voltage tube. Here they are

[1] A demonstration of radio-sodium produced by deuteron bombardment (bombardment by the nuclei of heavy hydrogen) and of radio-copper produced by neutron bombardment accompanied the lecture.

focused as a beam, which is accelerated down the axis of the tube to strike a target placed in a grounded extension of the vacuum-tube which projects downward into the observing-room beneath the high-voltage generator. Before striking the target where the transmutations are to be produced this beam of high-speed particles passes through a strong magnetic field, which is so adjusted as to allow only ions of the desired kind to impinge on the target, for example, protons (mass one) or deuterons (mass 2) or helium ions (mass 4). This equipment produces a bombarding beam of great homogeneity in kind and energy (energy-spread under one per cent.) at any desired voltage from 200,000 to about 1,150,000 volts, and the voltage (energy of the particles) is measured accurately and continuously by a voltmeter-resistor (10,000 megohms, measurements to one per cent.) enclosed in the large Textolite tube shown projecting at an angle downward from the high-voltage "ball." The extent to which our technique meets the requirements demanded by the quantitative work I shall now describe on the proton-proton interaction is perhaps best indicated by the observations shown in Fig. 2. The data of this figure are measurements on the resonance-transmutations produced by protons bombarding fluorine; the individual observations are numbered in sequence, and the agreement of the different points, especially on the steep portions of the curve, is a good measure of the constancy of the beam and the accuracy of our voltage-measurements. Furthermore, the extremely sharp rise of the curve at each resonance is in itself clear-cut evidence of the homogeneity of our bombarding beam. Nuclear resonances of this type provide a convenient scale of voltage-calibration points which obviously will remain constant.

(E) Direct Observations on the Nuclear Forces

It is interesting that one of the stated aims of the high-voltage program of our department when it was begun in 1926, although not carried through until ten years had elapsed, nevertheless still proved to be of the highest importance in formulating definite ideas regarding the atomic nucleus. At that time we set ourselves the problem of obtaining measurements on the collisions of protons with protons to see whether deviations could be observed from the predictions based on the ordinary inverse-square law of repulsion between like electric charges. Deviations of this kind would be direct experimental information concerning the forces which had been assumed for many years to hold together the primary particles which were constituents of the atomic nuclei—the nuclear forces.

Neutron-proton scattering: I should remark that the first direct observations of the nuclear forces were observations of the scattering of neutrons by matter. If nuclei are built up of neutrons and protons as we believe, there are three forces active in the structure of the nucleus, namely, proton-neutron forces, proton-proton forces and neutron-neutron forces. The observation of the proton-neutron forces, by the scattering of neutrons by hydrogen, gave direct evidence regarding one of these three—the proton-neutron interaction—but the absence of knowledge regarding the other two left the problem in a state of uncertainty. Our measurements of the proton-proton interaction have given the second leg of the triangle, so to speak, thereby defining the third, and have led to the remarkably simple conclusion that all these three types of interaction are nearly, although not exactly, the same. This was shown by Dr. Breit's theoretical analysis of our experimental curves.

Proton-proton scattering: The experiments by which we have measured the forces between two protons at very close distances of separation are really very simple in conception; the difficulties have been only the difficulties of obtaining

adequately quantitative measurements on all the factors involved. Protons are accelerated to a specified velocity (energy) by the high-voltage tube and pass through a "window" of aluminum foil into the scattering chamber of Fig. 3, which is filled with pure hydrogen gas at pressure of 12 mm. The diaphragms at the top define a 2-mm beam of protons passing through the gas of the chamber, and protons scattered by "billiard-ball collision" from a small segment of this beam at the center of the chamber in such a direction as to pass through the set of diaphragms or slits fastened to the ionization-chamber (marked IC No. 1) are recorded as individual counts by a linear amplifier, similar to a radio amplifier. The loss of energy of the protons in the aluminum foil and in the gas is checked by measurements of the fluorine resonances (Fig. 2), using a target at the bottom of the lower tube, giving us accurate knowledge of the velocity of the protons at the scattering volume. The latter is defined by the intersections of the lines extended from the two diaphragm-systems. The ionization-chamber with its diaphragm-system can be set at various angles to the primary beam.

The observations comprise measurements of the number of individual protons which are scattered through various angles (from 500 to 10,000 at each angle) by the hydrogen (protons) in the small scattering volume when a known large number of protons of the primary beam passes through this volume. These numbers are then compared with the numbers which are expected on the basis of the electrostatic repulsion between protons, given by a formula due to Mott. The ratio of our observed numbered of counts to the number expected (for each given angle and voltage) gives a measure of the deviations arising from forces superposed on the Coulomb repulsion. Fig. 4 shows a series of such ratios for angles from 15° to 50° and for energies from 600,000 to 900,000 volts. If the inverse-square law were obeyed, all these curves would coincide with the dashed line drawn through the ratio of unity. It is obvious that in addition to the electrical repulsion between protons, some other force is acting and that this force is much more important at 900,000 volts and 45° than for lower voltages and angles. The protons come only slightly closer together in a collision at 900,000 volts than they do at 600,000 volts, so the additional force sets in quite abruptly when the protons come within a certain distance of each other.

The most direct evidence that this "extra" force is an attraction, and not an added repulsion, is perhaps that of Fig. 5, which shows the ratios of our observed counts to those predicted by the Mott formula for a 45° angle and for energies from 200,000 to 900,000 volts. It is seen that at 400,000 volts the observed scattering is nearly zero. This corresponds to a situation in which the repulsion due to the like electrical charges of the two protons effectively is just cancelled by the attraction due to the nuclear force acting between them. At 200,000 volts the scattering at 45° is primarily due to the electrostatic repulsion, diminished somewhat by the nuclear attraction, whereas above 700,000 volts the scattering at 45° is primarily a result of the nuclear attraction between the protons.

Two features of our experiments which are of importance from a quantitative standpoint have not been mentioned. One is the fact that a thin gold leaf is mounted in the tube below the scattering chamber, with a second counter set to observe the number of protons scattered by the gold. This arrangement gives us a continuous measure of the proton-current passing through the scattering volume—a measure, in other words, of the total number of primary protons involved in a given scattering measurement. The second feature is the method used to give an "absolute" calibration (centimeters,

FIG. 1. THE 1,200,000-VOLT CONSTANT-POTENTIAL EQUIPMENT AT THE DEPARTMENT OF TERRESTRIAL MAGNETISM OF THE CARNEGIE INSTITUTION IN WASHINGTON. THIS EQUIPMENT HAS BEEN USED DURING THE PAST SEVERAL YEARS FOR STUDIES OF NUCLEAR TRANSMUTATIONS AND FOR DIRECT MEASUREMENTS OF THE LARGE FORCES WHICH BIND TOGETHER THE COMPONENT PARTS OF THE NUCLEI OF ATOMS. THE TARGETS AND OBSERVING INSTRUMENTS ARE IN A SEPARATE ROOM BENEATH THE HIGH-VOLTAGE EQUIPMENT SHOWN HERE.

grams, seconds) of the scale of our voltmeter. For this purpose we measure the number of protons scattered by a given small pressure of spectroscopically pure argon introduced into the scattering chamber. Since a nucleus of argon has 18 times as great a positive charge as a proton, the great repulsion between the nuclei of argon and the protons prevents the latter from approaching within range of the nuclear forces around the nuclei of argon, and the scattering is exactly "classical," that is, it follows the formulas based on the inverse-square law of electrostatic repulsion. This has been tested experimentally for various angles

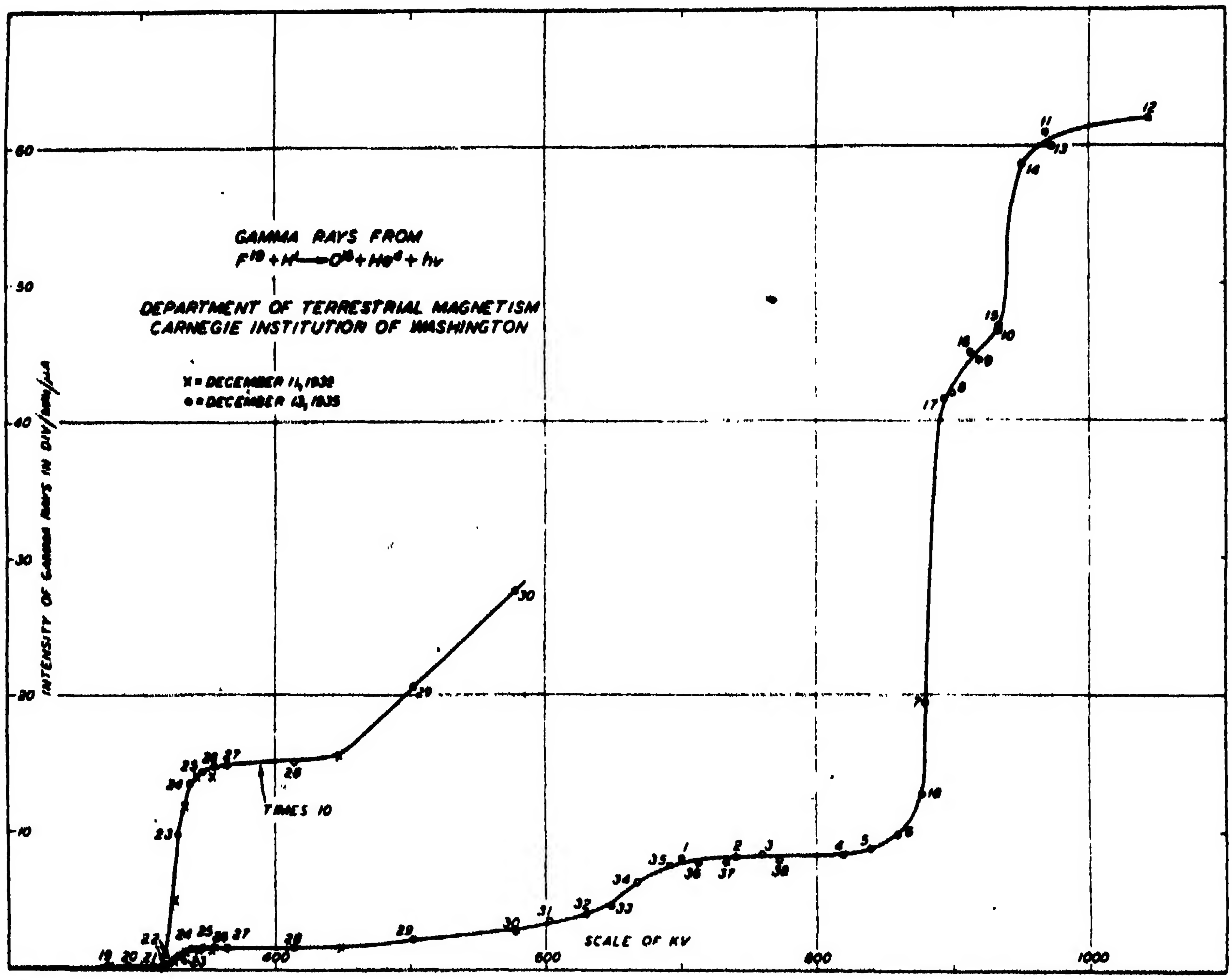


FIG. 2. MEASUREMENTS ON THE TRANSMUTATION OF FLUORINE BY PROTONS, PRODUCING OXYGEN AND HELIUM. THE STEEP PARTS OF THESE CURVES ARE EXAMPLES OF "RESONANCE"-TRANSMUTATIONS, AND PROVIDE EXCELLENT TESTS OF QUALITATIVE CHARACTERISTICS OF THE TECHNIQUE. THEY ALSO PROVIDE USEFUL REFERENCE-POINTS FOR CHECKING VOLTAGE CALIBRATION.

and voltages, using argon for the scattering gas (also using pure nitrogen and oxygen, which show very slight effects of the nuclear forces), with the result that we find it necessary to shift our original voltmeter-scale by somewhat less than 2 per cent. to give correct absolute values.

Direct conclusions based on the empirical evidence: From these data, then—and almost without reference to any form of theory regarding the nature of the nuclear forces—we are driven to the conclusion that when two protons are brought within a certain very close distance from each other a "new" force makes its appearance, superposed on the ordinary electrostatic repulsion between the two like charges of the protons. This new force sets in very abruptly and it is an attraction, which very rapidly overwhelms the large electrostatic repulsion and causes the protons to attract each other very strongly. This attraction is 10^{36} (1 followed by 36 zeros) times as large as the gravitational attraction between the two protons according to Newton's law, and in fact is about 10^{27} times as great as the weight of either proton. Small wonder that a high voltage is required to overcome the mutual electrostatic repulsion between charged particles when it reaches such a magnitude before the nuclear attraction comes into play! The "distance of approach" of the two protons for this range of nuclear attraction can not be spoken of with strict correctness, since the primary particles of matter are not mathematical points, but

have a certain diffuse (wave) character, but it is of the order of 5×10^{-13} cm. If a proton of this "size" is magnified to the size of a walnut, the atom of hydrogen would be several hundred feet in diameter, and the thumbs of the investigators who made these experiments would be more than ten million miles broad. On the same scale, the nuclear forces between the walnut-protons are not exhibited at all (under one per cent.) until they are brought within three or four inches of each other, the inverse-square law of electrostatic repulsion being perfectly obeyed for all greater distances of separation. Such a picture is too concrete, of course, to represent the cosmos of the atomic nucleus correctly, and should be viewed with a soft-focus lens for diffuseness, but it gives some idea of the degree to which these things are remote from our own scale of human dimensions.

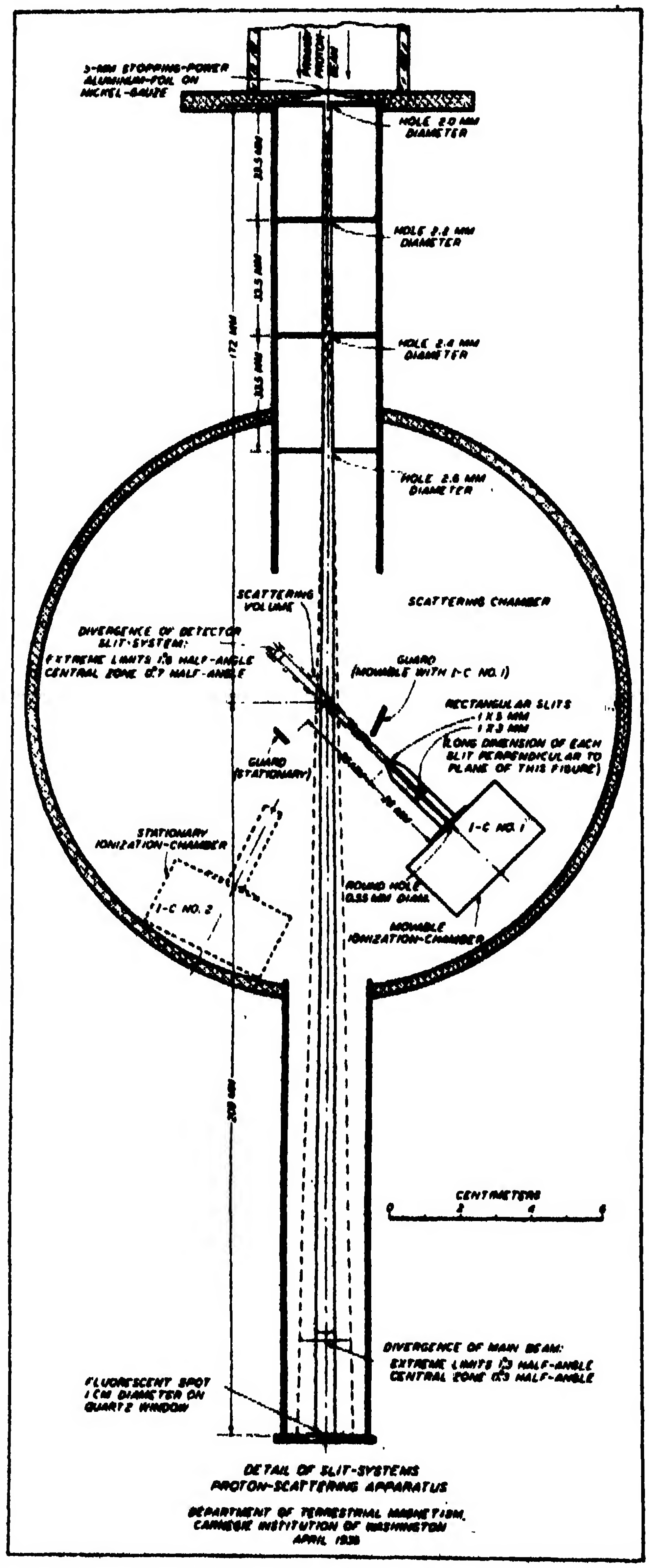


FIG. 3. DIAGRAM OF THE SCATTERING CHAMBER, USED FOR MEASUREMENTS OF THE LARGE NUCLEAR FORCE OF ATTRACTION WHICH WAS FOUND TO ARISE VERY ABRUPTLY WHEN TWO PROTONS (NUCLEI OF HYDROGEN) APPROACH VERY NEAR TO EACH OTHER.

(F) Atomic Characteristics of the Primary Physical Forces

Complexity versus basic concepts: The essence of scientific achievement or of what we may term understanding or knowledge or power over material things is the process of simplification, of reducing the apparent complexity of a whole collection of facts or experiences to a state of order in terms of a few basic ideas. This process of simplification has been carried out to an astonishing degree of completeness in describing the behavior of the physical world. The phenomena of chemistry and of molecular physics may be considered as expressions of the electromagnetic forces which act between atoms, and the laws of electromagnetic interactions as formulated in the wave-mechanics appear to be quantitatively valid, even when we concern ourselves with the mechanics of the interactions between various parts of the electronic structures of atoms. It is far from my intention to convey the idea that all the problems of molecular and chemical physics are solved—indeed most of these will undoubtedly still be with us when we have reached satisfactory solutions of the problems which we call "fundamental," if in fact we ever do.

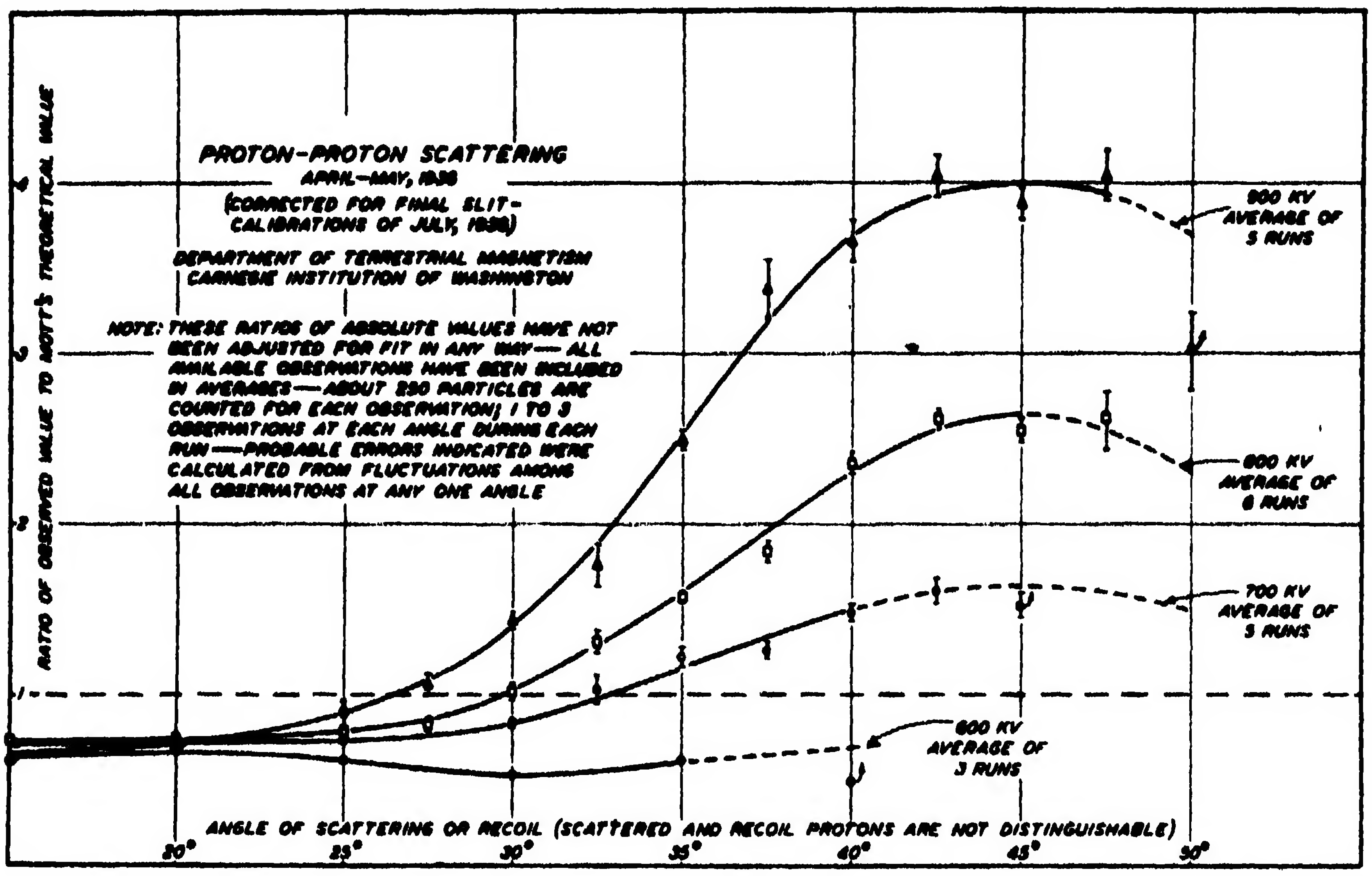


FIG. 4. RESULTS OF MEASUREMENTS ON THE ANGULAR SCATTERING OF PROTONS BY PROTONS ("BILLIARD-BALL COLLISIONS") AT ENERGIES FROM 600,000 TO 900,000 VOLTS. THE LARGE DEVIATIONS FROM THE VALUES EXPECTED ON THE BASIS OF THE ELECTRICAL REPULSION BETWEEN THE TWO PROTONS (EACH HAVING A POSITIVE CHARGE) SHOWS THE FAILURE OF THE FAMILIAR INVERSE-SQUARE LAW OF ELECTRICAL REPULSION DUE TO THE ADDITIONAL NUCLEAR ATTRACTION BETWEEN TWO PROTONS AT VERY CLOSE DISTANCES OF SEPARATION.

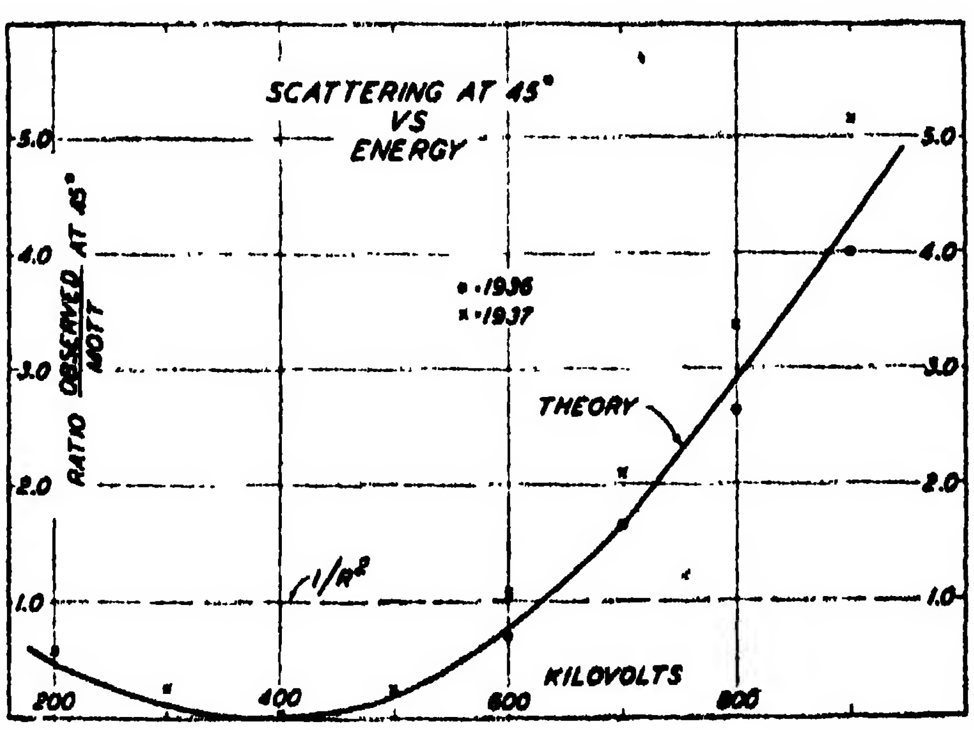


FIG. 5. MEASUREMENTS OF PROTONS SCATTERED TO 45° FOR A RANGE OF ENERGIES FROM 200,000 TO 900,000 VOLTS. AT LOW VOLTAGES THE PROTONS DO NOT APPROACH CLOSELY AND THE NUCLEAR FORCE HAS A SMALL EFFECT; AT 900,000 VOLTS THE EFFECT IS LARGE. THE ABSENCE OF SCATTERING AT 400,000 VOLTS IS DUE TO THE ELECTRICAL REPULSION BEING NEUTRALIZED BY THE NUCLEAR ATTRACTION. THE CURVE MARKED "THEORY" REFERS TO THEORY OF NUCLEAR FORCES, NOT THE CLASSICAL THEORY OF ELECTRICAL REPULSION WHICH PREDICTS POINTS ON THE DASHED LINE MARKED "$1/R^2$."

But difficulties of accounting in full for the detailed behavior of atoms in chemical reactions, for example, appear to us now as difficulties of *complexity* rather than as basic difficulties of *conception.* Although the picture and the words which accompany the formulas may quite possibly be changed again, as they so often have in the past as each new modification or refinement gave us a closer and closer approximation to the detailed and quantitative results of experiment, we are now inclined to believe that the laws of electrical and magnetic interactions as formulated in the wave-mechanics comprise a valid expression, although not necessarily a unique expression, of the essential laws governing molecular and chemical behavior, even though the mathematical complexities of a detailed treatment of the dynamics of the many-body problem will undoubtedly remain forever beyond our intellectual capacity.

When one stops to think, it is after all an exceedingly arrogant thing for a six-foot human being, with his five senses comprising the only routes of communication between his lone consciousness and the whole enormous, confusing, implacable, external world, to hope that he can arrive at *any* ideas or concepts sufficiently fundamental to encompass the behavior of all material things in a range extending from the smallest parts of the atom, a thousand-million-million times smaller than himself, to the most remote spiral nebulae he can observe with the 100-inch telescope, at a distance a billion-billion-million times larger than he is. This is quite without regard to the question whether the ideas he may arrive at are the *only* ideas having such properties. And it is perhaps a bit disturbing to realize the extent to which this arrogance seems to have been successful, viewing the scope and detail of modern physical science.

Let us turn, then, to a consideration of the three primary forces exhibited by matter, as indicated by Fig. 6. Gravitational forces are very small per unit quantity of matter, being of importance only when large amounts of matter interact with each other, as in astronomy. Even in engineering mechanics we neglect the gravitational attraction between the different parts of a building. As far as we know, or until we alter the meaning of the words "the force of gravity," the Newtonian forces are of no importance in atomics mechanics, being negligibly small in comparison with other atomic forces.

The electrical nature of matter: The electromagnetic forces are most common to our experience. As already remarked, all the forces of cohesion, impact, tension, compression, strength of materials, sound, light and chemical action are expressions of the electromagnetic forces between atoms and parts of atoms. During the last 40 years it has gradually been learned just what refinements of Maxwell's classical laws of electromagnetic interaction are necessary in atomic mechanics; in other words, refinements which become necessary in our analysis when we make it fine-grained enough to "see" the separate parts of atoms. These refinements or modifications are expressed in the quantum-theory in its modern form, called the wave-mechanics. As the word quantum indicates, one primary change or modification involves the introduction of an element of discreteness, limiting the infinite number of possible states of motion which might

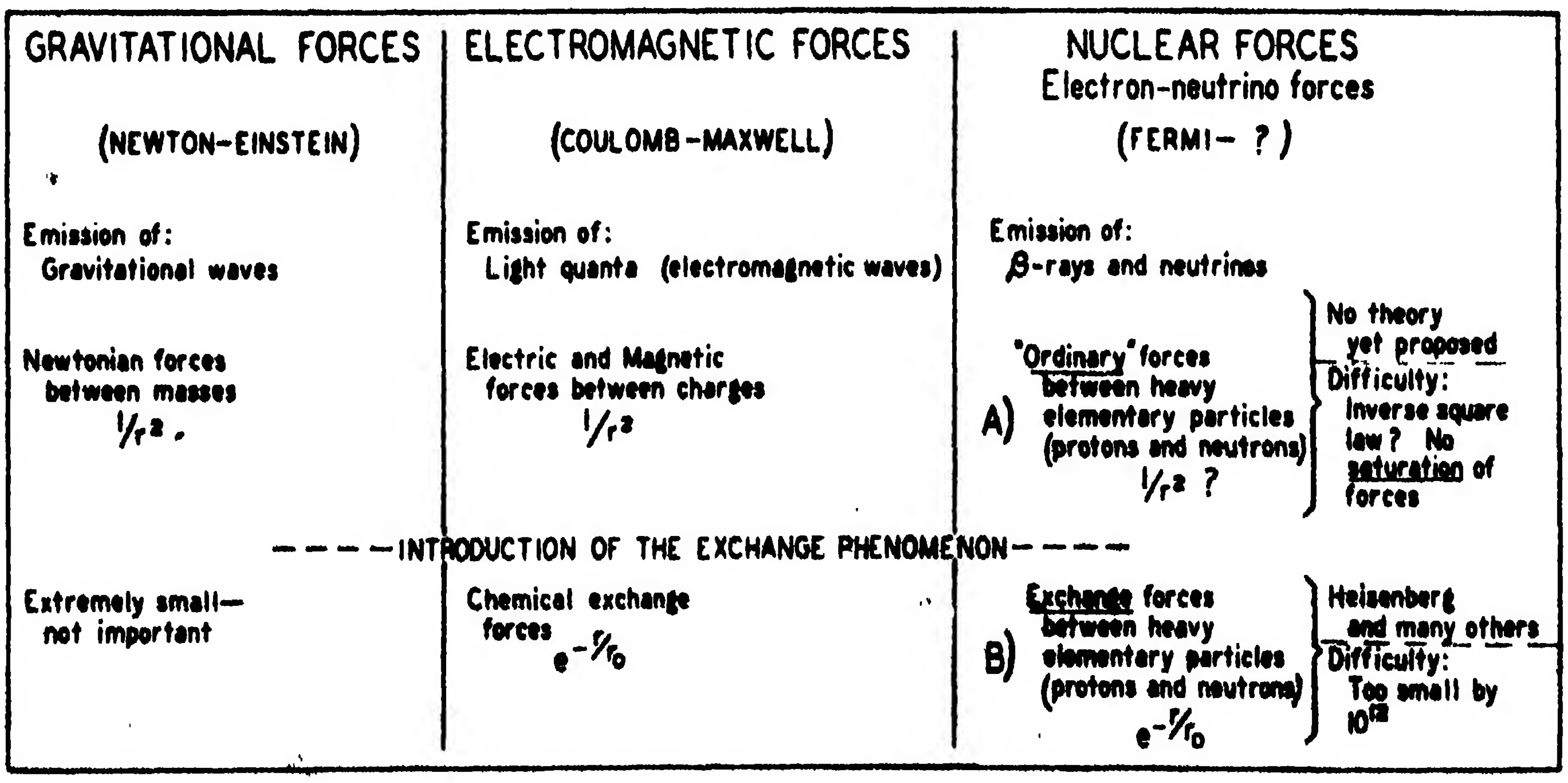


FIG. 6. CLASSIFICATION OF THE KNOWN PHYSICAL FORCES WHICH GOVERN THE BEHAVIOR OF ALL MATTER. AS INDICATED IN THE TEXT, THE FORCES WHICH GOVERN THE ATOMIC NUCLEUS ARE NOT YET WELL UNDERSTOOD, ALTHOUGH MANY OF THEIR CHARACTERISTICS HAVE BEEN DETERMINED BY EXPERIMENT.

occur to a finite series of steady states between which transitions occur, and atomic behavior corresponds to this discrete or discontinuous type of electromagnetic action. In any large-scale problem, however, the quantum-theory degenerates or irons out into the familiar electromagnetic laws.

The other primary modification of classical electromagnetic theory which has been found necessary in dealing with the mechanics of the outer structure of the atom is the introduction of the idea of the wave-nature of matter, as expressed in the modern form of the quantum-theory called the wave-mechanics. This formulation of the quantum-theory, developed since 1925, treats all material particles as "wave-packets." We need not concern ourselves here with the nature of matter-waves beyond saying that when we go down to the scale of atomic dimensions the simple picture of the various particles of matter as mathematical points has turned out to be inadequate, they are endowed with certain wave-characteristics, and the equations developed on this wave-basis, using the electromagnetic forces, have been almost completely successful in dealing with the previous difficulties encountered in the electromagnetic theory of the interactions between atoms and in the outer structures of atoms. The forces in a crystal lattice, forces of chemical interaction, the conduction of electricity in metals, electron-diffraction, atomic and molecular spectra, ferro-magnetism and similar problems are examples of its success. These basic ideas of wave-character and quantization or discontinuity, as incorporated in the formation of the wave-mechanics, have also proved successful to at least a considerable extent in treating the mechanics of the nuclear forces, which are by no means necessarily electromagnetic, and in fact may as well be considered at present as intrinsically non-electrical. The old hypothesis that matter is entirely electrical in nature, that the mass of a particle is simply the inertia of its electromagnetic field, is now a question of little interest, being at best largely a matter of words; most of us would prefer not to enlarge the word "electrical" to include everything we now know.

Exchange-forces: The exchange-phenomenon, referred to earlier, gives rise to what we call exchange-forces and is a sufficiently new and important addition to our ideas of the structure of matter to merit a brief description. The phenomenon of exchange refers to the necessity for us to take into consideration certain effects which arise from the fact that our atomic parts are similar. The importance of this exchange-phenomenon arises from the fact that, according to the wave-mechanics, atomic parts are not just mathematical points, but extend somewhat diffusely through a region of space which has a size greater than zero, and hence may overlap each other.

Referring to Fig. 7, we may inquire what happens when an atom with its normal atmosphere of electrons approaches a similar atom which has lost one or several of its outer electrons, forming what we call an ion. On the classical picture the orbits of the electrons are disturbed by the electrical attraction of the ion and a polarization of the normal atom occurs as it approaches the ion, giving rise to an extra attraction between them which varies as the fifth power of the distance between the two atoms, even on the basis of the inverse-square law of force between all the charged particles concerned. Using this picture, however, sharing or interchange of electrons between the two atoms can not occur until the atoms are so close together that the hills or barriers of electrical potential surrounding the atoms coalesce sufficiently to permit the electrons held by one atom to wander over to the other atom without climbing out of the "potential hole," which represents the energy of attraction of the

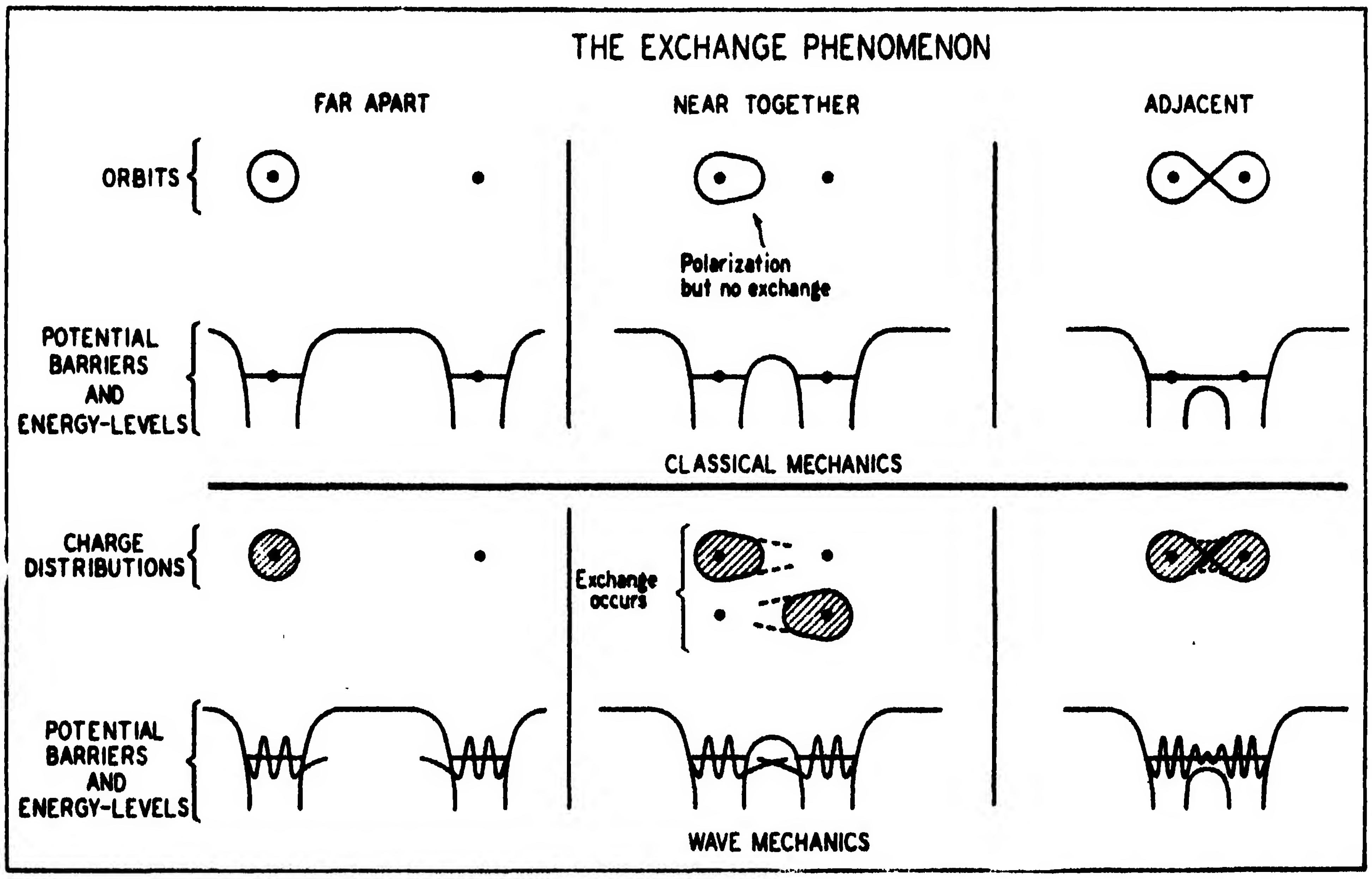


FIG. 7. DIAGRAM ILLUSTRATING THE "EXCHANGE-PHENOMENON" WHICH GIVES RISE TO FORCES BETWEEN ATOMIC PARTS WHICH WOULD NOT BE EXPECTED IF THESE PARTS BEHAVED AS PARTICLES OF ZERO-SIZE. AN IMPORTANT CONDITION IS THE FACT THAT NO TWO ATOMIC PARTS CAN SIMULTANEOUSLY HAVE THE SAME "QUANTUM-NUMBERS" (WHICH SPECIFY POSITION, VELOCITY AND ORIENTATION).

electron to an atom. The normal energy of a given electron attached to an atom is represented by an energy-level inside this potential hole, as shown in Fig. 7. On the wave-mechanics, however, there is a certain "leakage" of the matter-waves which correspond to the electrons of one atom passing directly *through* the potential hill or barrier between the two potential holes. Thus an electron can be exchanged between the two atoms *before* they are so close together that their potential holes, or spheres of attraction, coalesce. Such an exchange is of importance only if the energies of the two cases are similar, so that *resonance* occurs. The forces between the two atoms, even though they may be considered intrinsically as electrical forces, depend then not only on their distances apart, based on the inverse-square law, but on this phenomenon of exchange of charges, which gives rise to an additional energy-term in the equations, corresponding to the particles exchanging their charges when they are near to each other, with a certain frequency. It is exactly this type of exchange which is responsible for what we call the chemical forces, which are interactions between the outer parts of atoms which cause them to associate together and form chemical compounds. All atomic particles furthermore are endowed with intrinsic spin or angular momentum, and the exchange of spin can give rise also to a similar additional force. These extra forces are called *exchange-forces*, and they may be attractions or repulsions, depending on specific conditions.

In this connection, there is one requirement which is of fundamental importance, and which operates to give large effects dependent upon exchange. This is the law—called the Pauli Principle—which states that if two particles in an atomic system are not only similar but are indistinguishable, or identical in all

their properties, they can not both be in the same "quantum-state"—they can not have the same position, velocity and orientation. If more than one electron, for example, takes part in exchange, this law exercises a regulatory function with regard to the states which the several electrons can occupy, and thus may determine whether attraction or repulsion will arise. When particles are identical in this way, they may exchange their places and properties without actually changing the system under discussion in any way we can tell. The atomic parts have no serial numbers.

The nature of the forces inside atomic nuclei: We are accustomed to thinking of these exchange-forces between atoms as simply additional attributes of electromagnetic forces which arise when the analysis is made fine-grained enough to deal with atomic dimensions, although one may quite properly say that this identification is somewhat arbitrary. In an arbitrary way we might also consider the forces inside the nucleus to be further large modifications of the ordinary electromagnetic forces which apply to these still smaller regions of space inside the nucleus. For that matter we might equally well consider them as enormous modifications of the law of gravitation setting in abruptly at very short distances between massive particles, but the nuclear forces are so tremendously large and set in so abruptly at very short distances that it seems less arbitrary to regard them simply as another kind of force, obeying, however, the same requirements of fundamental discreteness and exchange as were found necessary in the quantum-theory or wave-mechanics obeyed by the electrically charged particles forming the outer structures of atoms. In addition, since the nuclear particles to a certain degree possess electrical charge and magnetic moment, the electromagnetic requirements of the wave-mechanics are imposed to the same degree on the nucleus, in respect to the radiation of electromagnetic waves (gamma rays), for example.

"Understanding" the nuclear forces: Fig. 6 also indicates briefly the status of our theoretical understanding of the nuclear forces. We know that the nature of these forces is intimately tied up with the phenomenon of the emission of beta rays, which are electrons (positive or negative) shot out of radioactive nuclei with a continuous distribution of energies. Fermi has made an attempt to explain the forces between the heavy particles in the nucleus as arising from exchange-interactions of the electrons and neutrinos associated with the heavy particles. Using the data available, however, these forces appear to be a million-million times too small to account for the known energies of binding of nuclei. The shape of the energy-distribution of the beta rays predicted by this theory furthermore does not agree with the observed distribution, although this difficulty may not be insoluble if the Fermi forces are made more complicated than one might like by the introduction of various derivatives of the functions used. Numerous modifications of the exchange-phenomenon have been considered, following the example of Heisenberg, involving exchange of charge, exchange of spin, exchange of both charge and spin and even the exchange of pairs of charges. None of these formulations appears satisfactory. At present there is no experimental evidence of great weight which shows that the forces inside the nucleus are specifically of the exchange-type or even largely so, but we all are inclined to believe them to be of this type, chiefly because forces of an "ordinary" type (derivable from a potential) do not exhibit the property of saturation. This refers to the fact, as you recall, that each particle added to a nucleus is bound to the rest by a total energy which is about the same, per particle, throughout the atomic table. With ordinary forces each particle interacts

FIG. 8. VIEW OF THE COMPLETED ATOMIC PHYSICS OBSERVATORY AT THE DEPARTMENT OF TERRESTRIAL MAGNETISM OF THE CARNEGIE INSTITUTION IN WASHINGTON.

individually with each other particle already present, and the energy of binding for adding another particle should be much larger if the initial nucleus contains many particles than if it contains only a few. Consequently, if one wants to keep the idea of ordinary potential forces, it will be necessary to assume forces which do not act independently between pairs of particles, but which actually are determined by the number of particles present. In this case the interaction between a pair of particles is itself altered when a third particle is added to the system.

I should remark that our experiments on proton-proton scattering exhibit a definite deviation in the variation with

angle which is roughly in agreement with the assumption of exchange-forces. Our curves show a deviation (about 10 per cent. excess scattering at 20° angle) from the curves which would be expected on the basis of nuclear theory for the simplest kind of scattering (spherically symmetrical), and this deviation has the sign (indicating a slight added repulsion) which is expected if exchange-forces are acting. The major features of the proton-scattering measurements, however, and of neutron-proton scattering measurements as well, are just as would be expected if an ordinary potential-well exists, giving rise to a strong attraction. Except for differences of detail, they do not indicate whether or not this potential-well represents exchange-forces instead of an ordinary potential. Exact and very comprehensive proton-scattering measurements over the voltage range from 0.2 to 5 million volts—or the fortunate future discovery of outstandingly characteristic proton- or neutron-scattering anomalies at higher voltages—may be expected to remove these present uncertainties as to the exchange-nature of the nuclear forces.

Intimately a part of this problem of the nuclear forces is the apparent lack of conservation of energy in the emission of continuous beta-ray spectra by radioactive nuclei (those which spontaneously

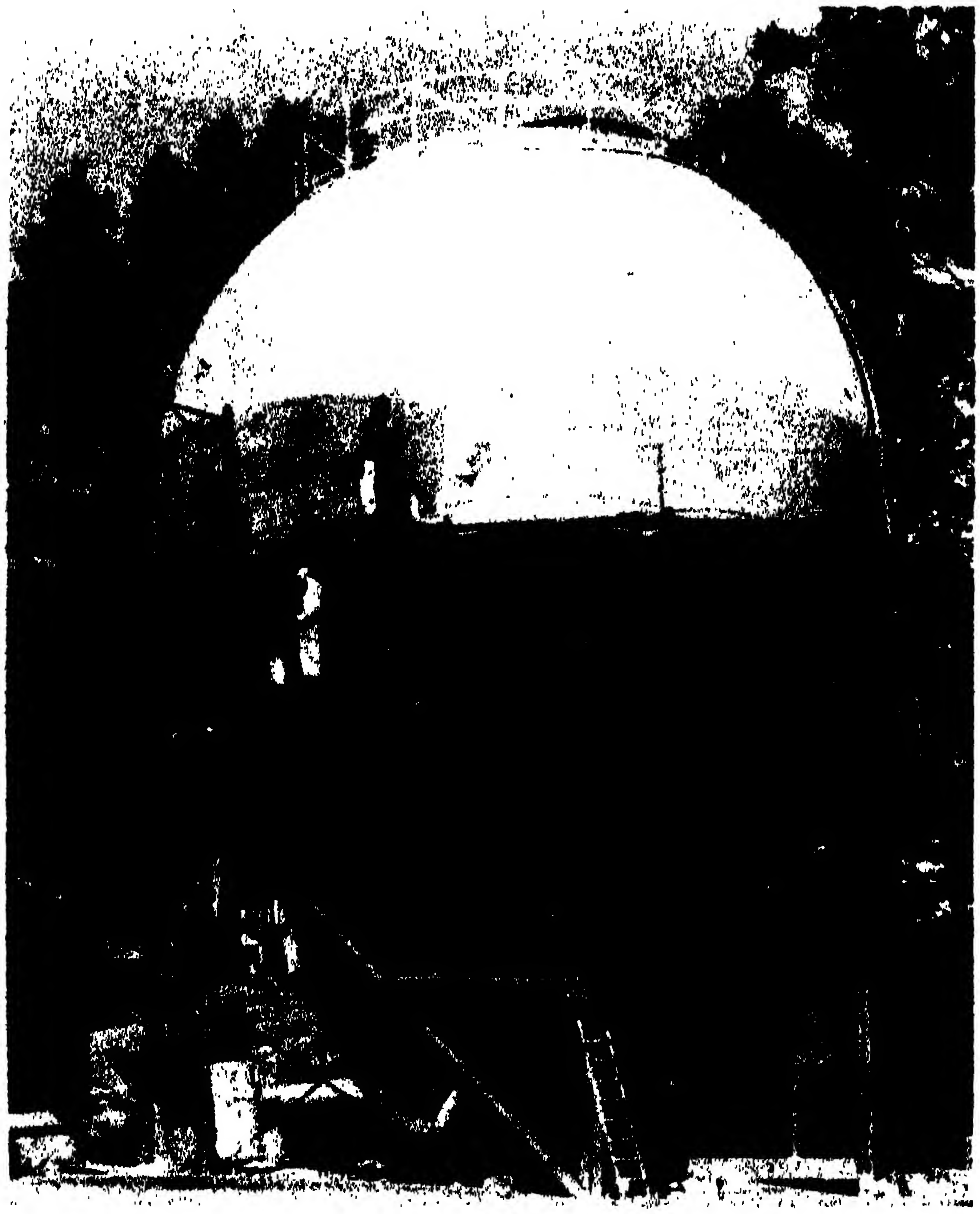


FIG. 9. STEEL TANK 55 FEET HIGH BEING BUILT TO HOUSE THE LARGE NEW EQUIPMENT FOR NUCLEAR-PHYSICS RESEARCH. ELECTRICAL INSULATION IS PROVIDED BY DRY AIR COMPRESSED TO 50 POUNDS PER SQUARE INCH IN THIS TANK. THE OBSERVATION-ROOM IS UNDERGROUND, TO GIVE EASE OF SHIELDING AGAINST INTENSE NEUTRON AND GAMMA RADIATIONS.

change from one chemical element to another by the emission of positive or negative electrons). The initial and final nuclei presumably being the same whether a fast or a slow electron is ejected, one must account for the apparent disappearance of some energy when the beta ray is a slow one. Physicists have "solved" this problem by inventing a new particle of mass equal or nearly equal to zero, the "neutrino," whose chief property is the ability to carry off this energy without detection—almost, in fact, without possibility of detection, since it has no other definite property except angular momentum or "spin" (without magnetic moment). Whether or not the neutrino can ever be more than a name for a difficulty depends on its being endowed either by theory or by experiment with more properties than it yet can be said to possess, thus showing its interaction with matter and making its presence known.

Another aspect of this general problem is the formulation of a concept of the detailed structure of a nucleus; at present it appears, as Bohr has emphasized, that this problem may remain permanently hopeless of detailed solution, since the sizes of nuclei are not much greater than the "sizes" of the particles of which they are composed, bringing us abruptly to a stop at the solid wall of difficulty presented by the detailed many-body problem. One further difficulty we meet at once in the nucleus is the present lack of a relativistic equation for the proton or neutron, something like the Dirac equation for electrons. Being unable to formulate a proper relativity-correction appears currently to be a serious obstacle in the way of any efforts toward a sound interpretation of the minor quantitative details of our proton-proton scattering measurements, for example. The interaction of the primary constituents of matter at still higher energies is also a logical extension of the problems encountered in the nucleus. In the region of cosmic-ray energies, certain facts about electrons and radiation appear to be established, but for the most part our ideas are subject to a large degree of uncertainty.

It is thus clear that our difficulties in understanding the forces which govern the atomic nucleus, now that we have begun to acquire a considerable fund of information about them, constitute very much of a fundamental problem in physics in the sense which I have indicated above—a failure of our concepts, a lack of a workable pattern for our thinking. It is also clear, many of us think, that the most hopeful direction for our efforts in seeking a solution of these difficulties is the extension of our quantitative experimental data on two-body heavy-particle interactions (proton-proton and proton-neutron), especially toward higher voltages, and the accumulation of similar data on the beta rays. The chemistry of nuclear reactions has its own intrinsic and conceivably practical interest, but acquiring exact data on interactions which are essentially simple, or at least as simple as possible (the beta rays always involve more than two primary particles), appears to offer perhaps the greatest likelihood of giving us a proper conceptual basis for understanding this microcosmos of atomic nuclei which surrounds us wherever we turn.

(G) Postscript—The Atomic Physics Observatory

This general discussion of our interest and work at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in the field of nuclear physics can hardly be concluded without making brief reference to the new high-voltage equipment the institution is now providing the department for extending our investigations along these lines. Fig. 8 is an exterior view of the new installation, which has been named the "Atomic Physics Observatory." The equipment comprises a steel tank 55 feet

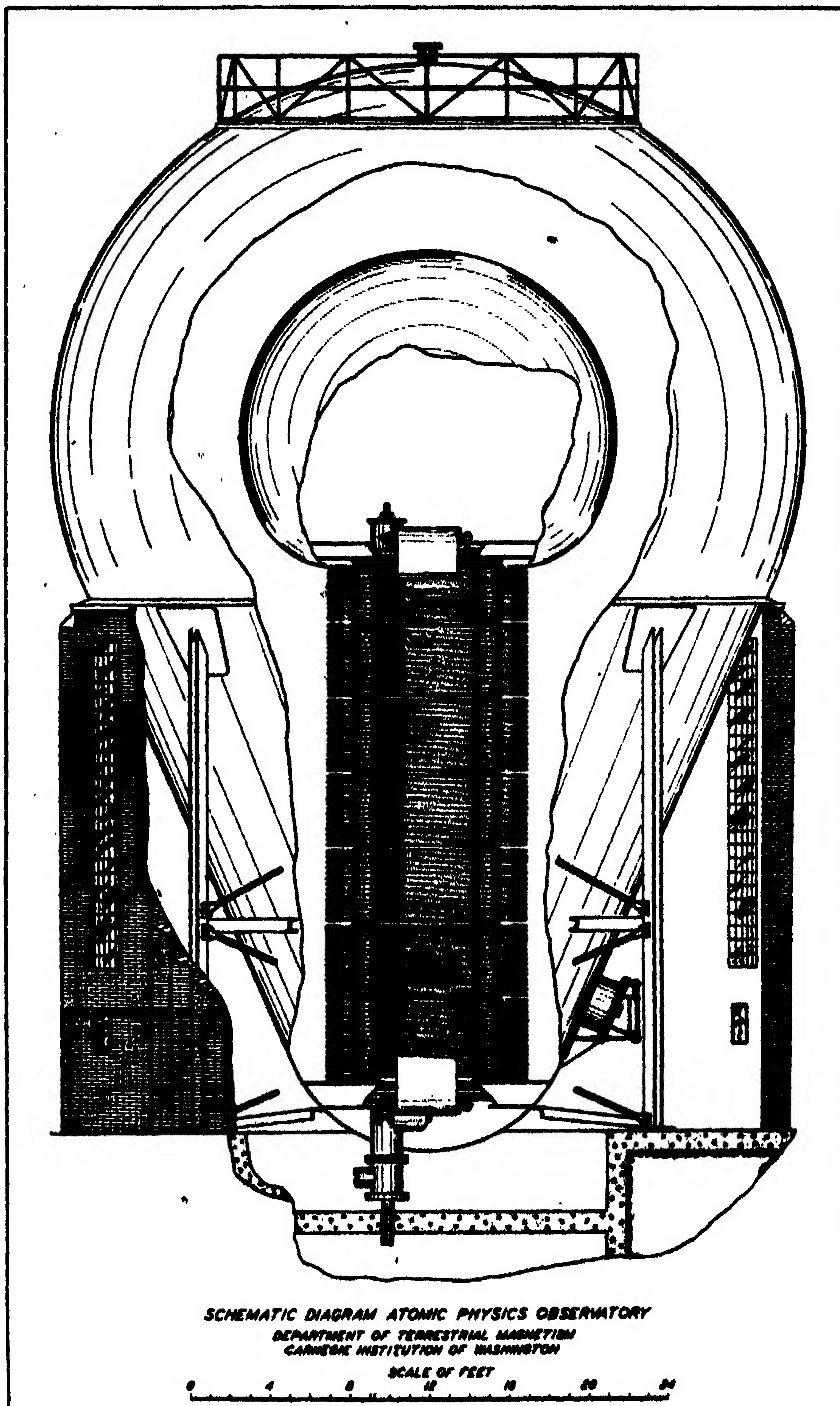


FIG. 10. SCHEMATIC DIAGRAM SHOWING THE INTERNAL CONSTRUCTION OF THE NEW 5,000,000-VOLT EQUIPMENT. THE TARGETS AND OBSERVING INSTRUMENTS AT THE BOTTOM ARE OMITTED. THE STEEL BALL SHOWN INSIDE THE TANK CAN BE CHARGED TO ANY DESIRED POTENTIAL UP TO 5,000,000 VOLTS. PROTONS, ELECTRONS OR OTHER BOMBARDING PARTICLES RELEASED AT THE TOP OF A LARGE VACUUM-TUBE REACHING INTO THIS BALL ARE ACCELERATED BY THIS POTENTIAL DOWNWARD TO TARGETS IN A ROOM BELOW THE STRUCTURE SHOWN. THE HIGH-VOLTAGE BALL IS 19 FEET IN DIAMETER AND IS SUPPORTED ON PORCELAIN COLUMNS 26 FEET HIGH.

high and 37½ feet in diameter, containing an electrostatic generator and vertical high-voltage tube, insulated for constant and accurately controllable potentials up to five million volts (and perhaps higher) by dry air at pressures up to 50 pounds per square inch. The electrical power of the generator is of the order of ten kilowatts. Beneath the tank is a target-room, completely underground (giving ease of shielding of personnel and instruments from the powerful intensities of gamma rays and neutrons), connected with our present high-voltage laboratory by a tunnel.

It is of some interest to remark that perhaps the most formidable technical problem encountered in the design of this equipment has been that of providing a suitable mechanical support for the 5-ton steel "ball," 19 feet in diameter, which is the high-voltage electrode, and which is supported on the outside tank (which moves slightly in the wind) and contains belts and other vibrating and energetic machinery. This ball had to be supported 26 feet above the base-platform on fireproof insulating columns (compressed air gives increased risk of fire), preferably of porcelain, which has notoriously bad mechanical properties in bending or tension. We therefore adopted a support design which is like a stack of seven flat-steel table-tops, each spaced from the next higher by four stubby legs of porcelain; the porcelain in this way is never subjected to anything except stresses of compression.

Fig. 9 shows the large tank, built by the Chicago Bridge and Iron Company, in process of erection. Fig. 10 shows a schematic design of the internal equipment, now in process of assembly (March, 1938). The architectural engineering was handled by Messrs. Norcross, Corning and Elmore, of Washington, and the building and concrete work by Mr. Raymond Burrows, contractor.

In conclusion, I must endeavor to express the profound gratefulness of my colleagues (Drs. Hafstad, Heydenburg and Breit) and myself to Dr. John C. Merriam, president of the institution, and to our colleague and director, Dr. John A. Fleming, for their generous and patient support of our efforts during the years we have been engaged on this program.

A UNIQUE STATION FOR BIOLOGICAL RESEARCH IN THE TROPICS[1]

By Dr. R. E. COKER

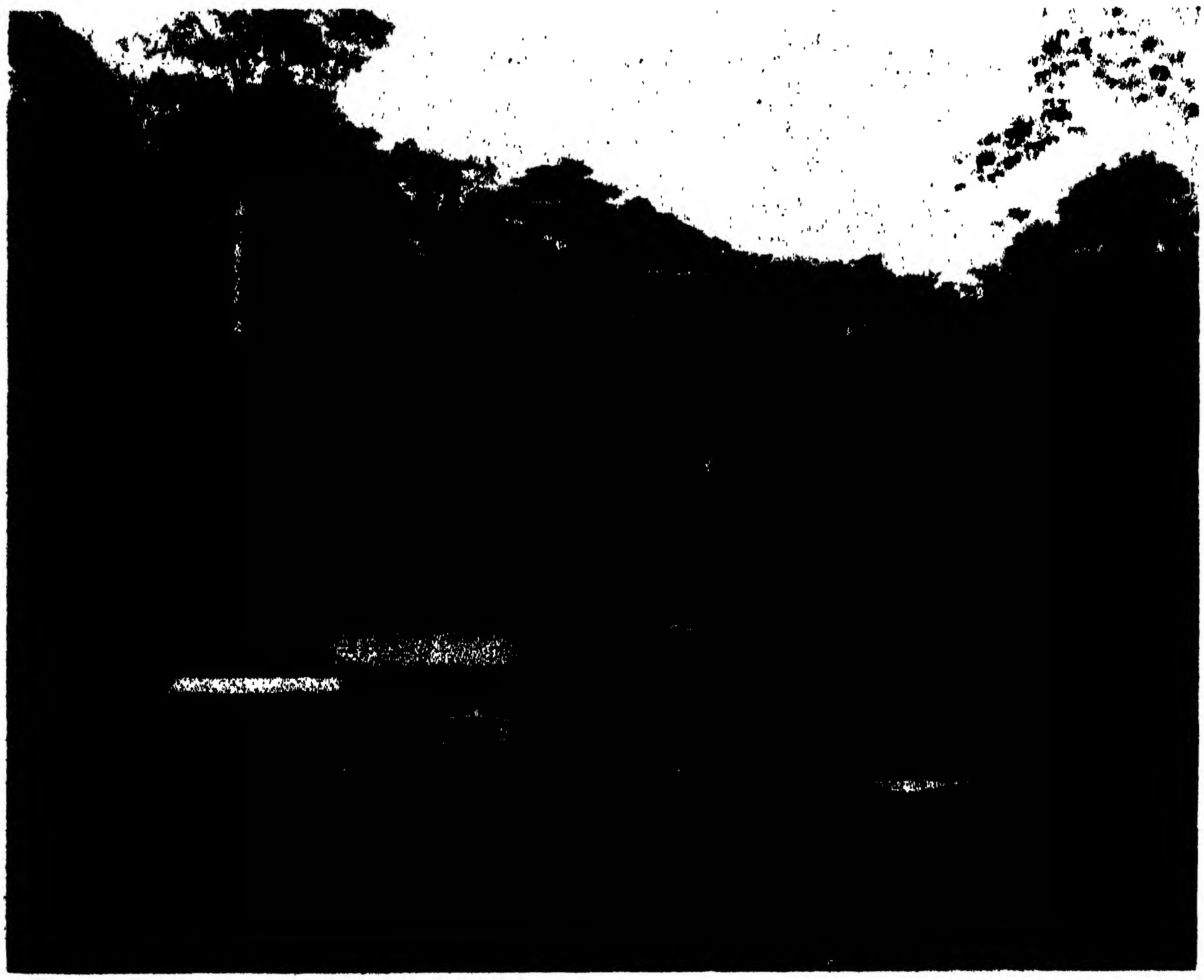
CHAIRMAN OF THE DIVISION OF BIOLOGY AND AGRICULTURE, NATIONAL RESEARCH COUNCIL

For hundreds of years the Tropics have served as a particularly potent lure to leading biologists in all parts of the world. It is not the result of mere chance that, to most of us, pictures of tropical regions have represented the embodiment of our conception of primeval conditions of life. Of course primeval conditions were not necessarily "tropical," but it is the torrid regions of the surface of the earth that of all terrestrial areas have most successfully resisted the encroachment of civilized man with the modifications of "natural" conditions that have inevitably marked his coming. That the high seas are undominated by man is attributable not so much to the biological conditions as to the physical conditions which make such areas impossible for permanent occupancy. With the Tropics, on the other hand, man meets not only the resistance of physical conditions, which are more easily overcome, but also that supreme luxuriance of plant and animal life which not only obstructs the initial invasion but also by guerilla tactics makes virtually impossible the effective consolidation of any extensive area of invaded territory. There we have manifested to the highest degree the forces of organic pressure which have generally prevented either the development of an advanced civilization or the long endurance of one that may have met temporary success against almost insurmountable conditions.

The Tropics are therefore the most favorable place for the study of a great diversity of both primitive and highly specialized types of plant and animal life and for inquiry into the conditions of animal and plant life in states almost entirely unmodified by human influence. Stark competitive conditions prevail, but the competition is between individuals and societies of animals and of plants rather than between wild animals and plants as opposed to relatively ineffective man. Few, if any, biologists who have attempted to carve a temporary path through the rich jungles, who have faced the prolific manifestations of plant and animal multiplication and evolution, who have contemplated the bewildering display of color, size and forms in fauna and flora, and who have given ear to the impressive alternations of silence and animal orchestration, have failed to derive an enduring intellectual stimulus.

Geographers will readily assure us that it is due to no accident that a populous and allegedly prosperous nation has developed in a strictly temperate region of the northern hemisphere. The United States has one, and only one, tropical continental possession, and that is the Canal Zone, but for its domination it proved necessary to modify laboriously and expensively the original natural conditions. It was not the physical difficulties encountered in Panama that so long baffled and effectually stalled the efforts to make a connecting waterway between the Atlantic and Pacific through the Isthmus of Panama. The real obstacles to be overcome were primarily biological and, as is universally recognized, it was

[1] The "author's" part is rather that of an editor availing himself freely of materials from the annual reports of Dr. Barbour and Mr. Zetek and the notes of Dr. I. F. Lewis, past chairman of the Division of Biology and Agriculture, National Research Council.

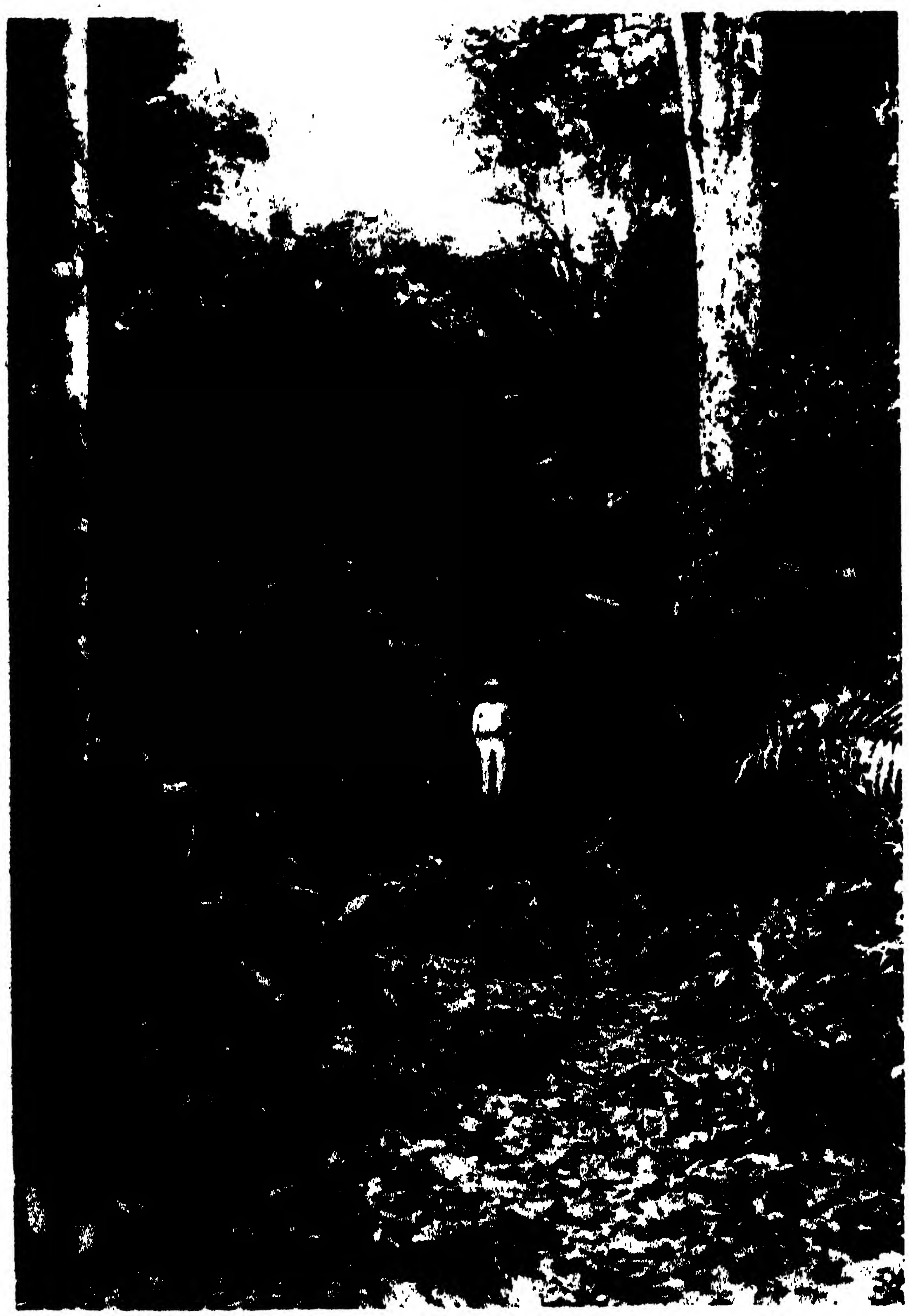


BARRO COLORADO ISLAND BIOLOGICAL STATION, SHOWING PORCH OF MAIN LABORATORY BUILDING; DR. BARBOUR'S HOUSE TO LEFT IN WOODS; MR. ZETEK'S OFFICE TO THE RIGHT; HOUSE FOR ELECTRIC GENERATOR IN FOREGROUND UNDER BIG COCONUT PALM.

the biological developments of the early part of the twentieth century rather than advances in engineering that made possible the building of the Panama Canal.

The Canal Zone itself is a narrow and extremely modified tropical area, but it embraces a remarkable island—a body of land that is insular in a double sense. Topographically, a formerly prominent forested headland now emerges from the surface of a large artificially formed lake as a true island in the physical sense. Biologically, this body of land, some three and one half miles in diameter, is a floral and faunal island, to be perpetuated as such since it was officially designated by Governor J. J. Morrow in 1923 as a national park, to be reserved for scientific uses. In 1924 the island became the home of a research establishment under the auspices of the Institute for Research in Tropical America, then an agency of the National Research Council. Although this laboratory has at times led a precarious life, it has continued to exist, to develop healthfully and to serve as a unique and highly useful institution for tropical research, chiefly because of the unfailing interest and unflagging support of Dr. Thomas Barbour, chairman of the executive committee of the institute, and the consistent and invaluable volunteer service of Mr. James Zetek.

Barro Colorado Island, with an area of about six square miles, has a maximum



WILLIAM MORTON WHEELER TRAIL.

SLOTHIA ISLAND AND LAKE FROM LABORATORY, MAINLAND BEYOND.

elevation of 452 feet above the surface of the lake. Almost entirely wooded, it is surrounded by Gatun Lake, with a shore line of more than 100 miles and hundreds of bays and inlets, fed by the Chagres and Gigante Rivers. It possesses the highly advantageous qualities of being accessible at no great expense, having an excellently equipped laboratory with an administration hospitable to all interested and qualified scientists and harboring undisturbed fauna and flora in great diversity and abundance. The natural conditions are indeed modified only by the provision of the necessary laboratory, living quarters, landing docks and the trails necessary to give access to the various parts of the reservation on which studies may be pursued.

Among the forms of animal life on the island are 250 species of birds and 53 species of mammals, including opossums, sloths, anteaters, armadillos, peccaries, deer, tapir, agoutis, squirrels, raccoons, coatis, ocelot, bats, capuchin monkeys, night monkeys and black howlers, to say nothing of insects too numerous to mention.

Accessible from the laboratory as headquarters are the tropical forests of Panama and particularly the new Forest Reserve in the Canal Zone—"A singularly beautiful area of really good luxuriant forest, lots of interesting plants, birds, insects, etc., and a chance to see the old 'gold road' which originally ran from old Panama to the head of navigation in the Chagres River at Las Cruces—for the new concrete road cuts directly across this, the oldest road on the American continent—indeed the original cobblestone paving can plainly be seen. . . ." In this Reserve, set aside by Colonel Harry Burgess in 1930, are walks from which one can not get lost and from which a lot of tropical wild life can be observed.

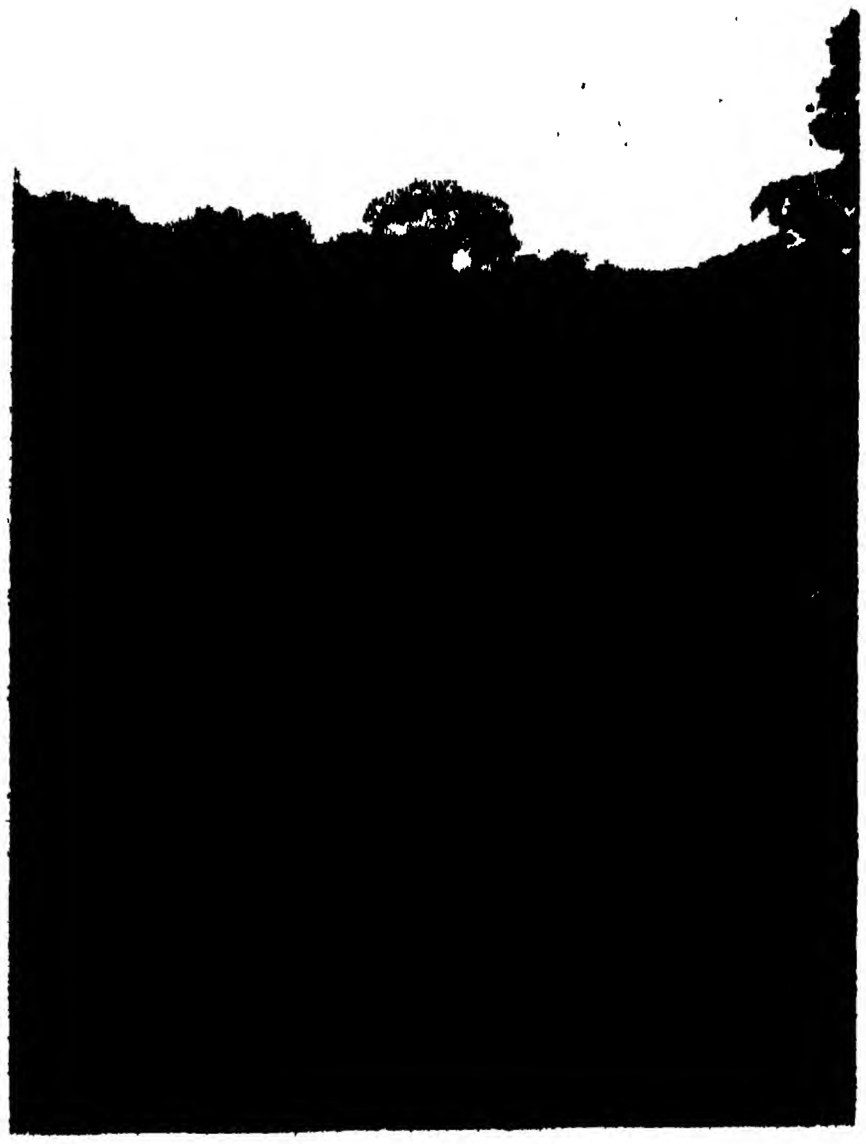
Although unfortunately the institution has never enjoyed the assurance of permanent financial support, it has already

acquired a notable history in service to scientists of diverse interests and in biological productivity, as evidenced by the extended list of publications made possible wholly or in part through research conducted in or from the Barro Colorado Island Biological Station in the Panama Canal Zone. The number of published papers now credited to the laboratory—and the list must unfortunately and unavoidably be incomplete—now totals 316, or an average of more than twenty-two per year. Besides yielding reports of mainly technical interest the laboratory

"MY TROPICAL AIR CASTLE," OF FRANK M. CHAPMAN.

INLET ON NORTH SHORE OF BARRO COLORADO ISLAND.

has contributed its part to such books of popular appeal as Standley's monograph on the "Flora of the Panama Canal Zone," Sturgis' "Field Book of Birds of the Panama Canal Zone," Chapman's "My Tropical Air Castle," Snyder and Zetek's "Termites and Termite Control" (two chapters contributed to the volume published by the University of California), Weston's "Fungi of Barro Colo-



ROOF OF THE JUNGLE FROM THE LOOKOUT ON HIGHEST POINT OF THE ISLAND.

rado," Carpenter's "Field Study on the Behavior and Social Relations of Howling Monkeys," Bailey's "Palms of Panama," Rau's "Bees and Wasps" and Schneirla's "Studies on Army Ants in Panama."

The list of names of those who have worked in this laboratory constitutes an impressive register of contemporary biologists interested either in tropical science or in biological research for which material must be sought in tropical regions. Among such are W. C. Allee, Frank M. Chapman, O. F. Cook, F. E. Lutz, Maynard M. Metcalf, George H. Parker, Alexander Petrunkevitch, Franz Schrader, W. H. Weston, W. M. Wheeler, G. B. Wislocki, L. L. Woodruff and Robert M. Yerkes, to cite only a few names typifying a diversity of biological fields of activity. Even more impressive is the great number of letters from former table occupants containing expressions of grateful and even enthusiastic appreciation of the courtesies and facilities extended to them and the effective aid rendered to their efforts in research.

Such is the one tropical biological research station maintained under the American flag and at present supported only by table subscriptions from eight institutions,[2] the modest fees from visiting scientists and voluntary contributions from a limited number of personal friends of the laboratory. Universities, biological societies, other institutions for the advancement of biological research and biologists in general may well be interested and concerned with the future of so valuable an agency for biological science.

[2] The following institutions supported the island through table subscriptions in 1937—Smithsonian Institution, Dartmouth College, Harvard University, Yale University, New York Zoological Society, Carnegie Institution of Washington, University of Chicago and the American Museum of Natural History. Northwestern University will resubscribe for 1938, and also the University of Michigan.

DR. ALBERT EINSTEIN

PHOTOGRAPH TAKEN ON JUNE 6, WHEN HE GAVE AN ADDRESS AT SWARTHMORE COLLEGE.

THE PROGRESS OF SCIENCE

THE BUILDINGS OF CAMBRIDGE

At the meeting of the British Association for the Advancement of Science, held in Cambridge from August 14 to 24, a forecast of which was given in the September issue of The Scientific Monthly, arrangements were made for closer cooperation between the British and American associations. There will be an annual exchange of lecturers at the meetings of the two associations and there will be honorary representatives of each association on the governing body of the other. There were nearly a hundred Americans at the Cambridge meeting, the largest number in its history, doubtless in part attracted by a meeting at the university which has so greatly contributed to the advancement of science in England.

Not a little of the unique charm and beauty of the University of Cambridge springs from the variety in architecture and the widely variant historical background of its storied buildings. No building of the university is without its own richly colored tale, now historical, with its roots buried in a past incredibly remote to American eyes, now as modern as research in nuclear physics. From the days of the founding of St. Peter's College by Hugh de Balsham, Bishop of Ely, in 1284, and of Clare College in 1326 by Lady Elizabeth, granddaughter of Edward I, to the erection of the new chemical laboratory and the newly constructed laboratory of experimental physics with its elaborate facilities for high voltage research, exists an unbroken span of academically eventful and pro-

Etching by R. Farren.

PETERHOUSE, THE OLDEST OF THE CAMBRIDGE COLLEGES

Etching by A. Brunet-Debaines.

THE CAM NEAR TRINITY COLLEGE, WITH THE TOWER OF ST. JOHN'S COLLEGE CHAPEL

Engraving by J. LeKeux.

JESUS COLLEGE. FROM THE MEADOWS

ductive years. Epochs can be dated by the colleges which they brought into being, as the loosely organized system of unofficial hostels which obtained in the twelfth and thirteenth centuries gradually crystallized into the system of colleges as we know them to-day. Pembroke Hall in 1347, King's College in 1441, Queen's College in 1448, and Trinity College in 1546, served as landmarks of the passing of centuries, and between them came all but four of the remaining colleges of the university. Each added its own unique contribution to the community on the Cam. How early the organization program of the colleges was established in essentially its present form is indicated by the fact that only two, Downing College, founded in 1800 by Sir George Downing, and Selwyn College Public Hostel, founded in 1882 in memory of George Augustus Selwyn, late bishop of Lichfield, have appeared since the coming of Sidney Sussex College in 1596.

A very ancient group of colleges, connected with a university yet more ancient, may still be surrounded with buildings very variable in age and style. No building of the University of Cambridge is more important than its library. Over 800,000 volumes and 10,000 manuscripts are housed in the university library, whose spacious construction and lighting fit it admirably for a study as well as for a home of books. Here is kept the precious *Codex Bezae*, consisting of a copy of the Four Gospels and the Acts of the Apostles. It was presented to the university in 1581 by Theodore Beza, and is believed by Scrivener to have been derived from an original dating not later than the third century.

No less famous than the university library is the Acton Library, presented by Viscount Morley in 1902 and containing 59,000 volumes. It is entitled by the copyright act to a copy of every book published in the United Kingdom,

Etching by R. Farren.

THE FIRST COURT, SIDNEY-SUSSEX COLLEGE

and large sums are spent in the purchase of foreign books each year.

The Fitzwilliam Museum, with its collections of paintings, coins and ancient marbles, is one of the more striking members of the university grouping. The museums and laboratories of science cover much ground near the center of the university. They were formally opened by King Edward in 1905. Inconspicuous in its setting as it is great in its place in world science, the Cavendish Laboratory of Experimental Physics, whose new director, Professor W. L. Bragg, has but very recently come from the National Physical Laboratory to take up his post, faces on Free School Lane. Outwardly, it is almost crowded from the street by the pressure of the buildings around it, but within evidences of the work of Maxwell, Rayleigh, Thomson, Rutherford and other world figures who have contributed to its name speak for themselves.

In its buildings, no less than by the work done in them, the University of Cambridge need take second place to no other educational institution in the world.

Caryl P. Haskins

CHEMISTRY AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

The new Crellin Laboratory of Chemistry has been opened at the California Institute of Technology. It is the gift of Mr. and Mrs. Edward W. Crellin, of Pasadena, whose interest in the work in chemistry at the institute was initiated through their friendship with Mr. Charles W. Gates, one of the donors of the Gates Laboratory of Chemistry, built in 1916.

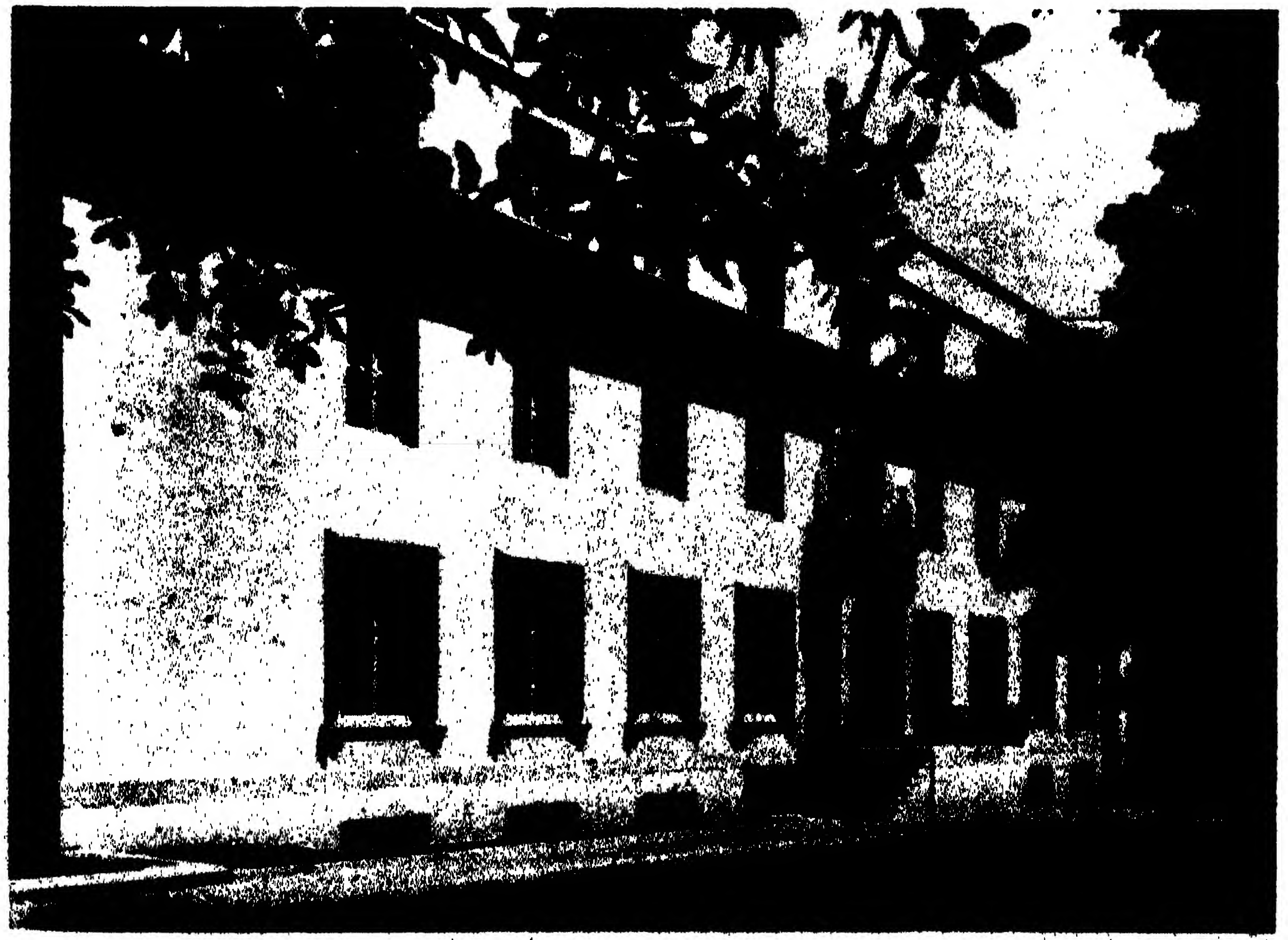
The Crellin Laboratory, which is adjacent to and connected with the Gates

Laboratory on one side and the new Kerckhoff Laboratory of the Biological Sciences on the other, has three floors above ground, each about 60,000 square feet in area, and in addition a basement and sub-basement. The building contains two classrooms and three laboratories for undergraduate instruction in organic chemistry; aside from these rooms, it is devoted entirely to graduate study and research. The second and third floors are equipped for research in organic chemistry, including especially the chemistry of substances of biological significance, and the first floor, basement and sub-basement are to be devoted to research in physical chemistry and structural chemistry, including photochemistry, magnetochemistry, spectroscopy and x-ray and electron diffraction.

At the dedication exercises of the Crellin Laboratory, addresses were made by Dr. Robert A. Millikan, chairman of the executive committee of the California Institute of Technology, and by Dr. Linus Pauling, director of the Gates and Crellin Laboratories. Dr. Millikan spoke on the development of chemistry at the institute. Of its early years he said:

In the spring of 1916 all of us scientific ground squirrels, who all over the United States come up occasionally to sun ourselves at the tops of the holes in which we are burrowing, found the news spreading from hole to hole that a new laboratory of physical chemistry was being started at Pasadena, and that this laboratory was to be under the direction of Arthur A. Noyes, who henceforth expected to oscillate between Boston and Pasadena.

The prestige of Dr. Noyes's name was what gave this news particular interest and currency, for the Institute of Physical Chemistry which Dr. Noyes had founded and directed at the Massachusetts Institute of Technology had already become, through his own work and that of the group of brilliant young men who had



George D. Haight

THE CRELLIN LABORATORY OF CHEMISTRY

ARTHUR AMOS NOYES
AT THE ENTRANCE OF THE GATES LABORATORY OF CHEMISTRY, OF WHICH HE WAS DIRECTOR FROM ITS FOUNDATION IN 1916 UNTIL HIS DEATH IN 1936.

DR. LINUS PAULING
PROFESSOR OF CHEMISTRY, DIRECTOR OF THE GATES AND CRELLIN LABORATORIES OF CHEMISTRY OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY.

come out of it, the most outstanding laboratory of its kind in the country. Indeed, Dr. Noyes himself was already regarded as the most influential of the founders and inspirers of physical chemistry in the United States.

Within a few months of this time Dr. Noyes, whom I had never met before, and his old-time M. I. T. friend, Dr. Hale, whom I had known well since 1896, came to my door in the Ryerson Laboratory of Physics at the University of Chicago saying they wanted to talk over plans and discuss possible personnel for the new "Gates Chemical Laboratory." I first saw this laboratory in January, 1917, when I stopped here for a week to give a few lectures in Throop Hall on my way back to Chicago from Berkeley, where I had been giving the so-called Hitchcock lectures. Let me describe what I saw then. Just two buildings on this campus, namely, Throop Hall and the Gates Chemical Laboratory, the rest weeds and dead or dying orange trees. Thirty-seven students all told had up to that date, January, 1917, taken the bachelor's degree from this institution, which in 1908 had announced to the world that it proposed to cease to be essentially a manual training high school and become one of the outstanding scientific and engineering schools of the country.

I marvelled then and I marvel now at the intrepidity, as well as the faith and the vision of the men who, led by George Ellery Hale, took the responsibility of making such an announcement. There was not a hundred thousand dollars of endowment in sight when they made it.

By 1917 there were a few of them who had stepped up and backed up their words with enough of their own funds to provide some small beginnings of advanced educational facilities. Mr. Arthur H. Fleming and his daughter, Marjorie, had bought the present campus, and with the aid of other public-spirited citizens had provided for the cost of Throop Hall, erected in 1910.

The first provision for advanced work in chemistry or any other science was made six years later in 1916, when the brothers Charles and Peter Gates came forward and built the first wing of the Gates Chemical Laboratory and Marjorie Fleming provided a fund for research in chemistry. All honor to these pioneers, who ventured before there was any assurance of success. Ninety-five per cent. of all business ventures fail, and I suspect the record of philanthropic enterprises is not much better. The *"enterprisers"*—the men who start things off *and make them go*—richly deserve all the credits and all the social rewards which they ever get. Thus chemistry, through the Gates brothers, made its start at the California Institute of Technology.

EARL BALDWIN McKINLEY

Earl Baldwin McKinley, dean of the medical school, professor of bacteriology and director of medical research, George Washington University, was one of the six passengers aboard the Hawaii Clipper which apparently plunged into the Pacific Ocean at one of its deepest points on July 28, 1938.

Earl McKinley was born at Emporia, Kansas, on September 28, 1894. He entered the University of Michigan on the combined curriculum in letters and medicine, receiving the baccalaureate degree in 1916. The world war interrupted his work in the medical school; he entered the service on May 7, 1917, and was discharged on August 8, 1919, with the rank of first lieutenant, having seen action overseas in the Marne offensive of July and August, 1918. In September, 1919, he returned to the university completing the medical course in 1922. During this period he served as an assistant in bacteriology as well as an instructor in physiological chemistry. In these capacities he came into direct contact with Dr. Novy, whose stimulating influence he frequently acknowledged and whose advice and aid he constantly sought.

Shortly after completing the required program of study in medicine and before entering on an internship for which he had qualified, Dr. McKinley was appointed assistant professor of bacteriology and pathology at Baylor University, Dallas, Texas. While there he had occasion to investigate a number of disorders, especially bacillary dysentery. These experiences crystallized his thoughts and he realized his interests were in research rather than the practice of medicine; therefore, in the spring of 1924, although his accomplishments had been rewarded by advancement in rank, he applied for and was granted a National Research Council fellowship in the medical sciences for study abroad. A year was spent with Professor Bordet at the Pasteur Institute in Brussels. This contact with foreign workers was of inestimable value and revealed that medical problems know no international boundaries.

While residing in Belgium he accepted an appointment as assistant professor of bacteriology in the College of Physicians and Surgeons of Columbia University, returning to New York in the fall of 1925 to assume his duties. For two years he shouldered his full share of the regular instructing load and in addition, attempted to unravel the mysteries of a number of diseases such as poliomyelitis and lethargica encephalitis. An inherent faculty for organizing and administration led to his selection in the establishment of the division of bacteriology when Columbia University founded the school of tropical medicine in Puerto Rico. It was during this activity that he became aware of the paucity of knowledge regarding diseases seemingly indigenous to the tropics and the importance these diseases might assume as world problems with the development of aviation.

THE LATE DR. EARL BALDWIN McKINLEY
DEAN OF THE MEDICAL SCHOOL, PROFESSOR OF BACTERIOLOGY AND DIRECTOR OF MEDICAL RESEARCH, GEORGE WASHINGTON UNIVERSITY.

Accordingly he relinquished his connections in New York and arrived in Manila early in June, 1927, to take the position as field director with the International Health Division of the Rockefeller Foundation. He was charged with the duty of reorganizing the public health laboratory service in the Bureau of Science cooperating with the Department of Health of the Insular Government. This assignment was satisfactorily consummated within the year and he found time to assemble the data for and write a monograph entitled "Filterable Viruses and Rickettsia Diseases." Having accomplished the task for which he was originally sent to the islands and fearful lest the projected plans of the foundation would entail him in endless administrative details and thus submerge opportunities for experimentation, he was quite willing to rejoin his old department at Columbia when the call came in the spring of '28. The appointment was that of professor of bacteriology and director of the school of tropical medicine of the University of Puerto Rico. He took up his duties in San Juan shortly after the island had experienced one of its most devastating tornadoes, where he had the unusual opportunity of observing at first hand many tropical diseases modified by exposure and famine. For three years he devoted himself unsparingly to the development of the school and hospital. In the winter of 1931, in collaboration with the writer, studies on leprosy were begun. Attempts were made to cultivate the causative agent of the disease and to transmit the malady to laboratory animals. The results of these experiments were published, and in 1937 Dr. McKinley spent his sabbatical leave in the Philippines confirming and extending these investigations. He had with him on the flying boat a number of specially prepared substances which were to be used in the skin-testing of patients with leprosy in Manila.

In September, 1931, he accepted the deanship of the medical school of George Washington University and took up his residence in Washington. In this new environment, the prodigious energy of the man was unleashed. He was a born leader and in the capital the multiplicity of scientific organizations with which he promptly affiliated responded to the stimulus of his personality. His keen, active, versatile mind disclosed an eagerness to share his experiences; he seemed to know every one connected in any way with the medical sciences. He was especially active in the American Leprosy Foundation and in the Academy and the Foundation for Tropical Medicine. As a member of the executive committee of the American Association for the Advancement of Science, he gave unstintingly of his time, and his contributions to the work of the association were significant and far-reaching. He was on the editorial committee of *Science* and was to have become in the autumn one of the editors of THE SCIENTIFIC MONTHLY.

One might conclude that the diversification of interest would preclude active participation in research, but such was not the case. He continued his investigations of tropical diseases. Under the sponsorship of the National Research Council he conducted a survey of tropical medicine, spending much time abroad in the gathering of the data. On the disastrous voyage he was extending this study by taking samples of the microbic content of the air at various points over the Pacific, in an effort to unravel the enigma of the transoceanic spread of disease. His untimely disappearance just as he was equipped for still finer things has removed prematurely a worker who was associated in a very significant fashion with an unusually large number of activities. His death is a tragedy for his friends, and science is prematurely deprived of one who had much to give.

MALCOLM H. SOULE

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EMERGENCY AND PERMANENT CONTROL OF WIND EROSION IN THE GREAT PLAINS[1]

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I

SPECTACULAR dust storms of 1934 to 1937, which scattered rich soil from the Great Plains to places beyond the boundaries of continental United States, have brought into sharp relief the vital problems of agriculture in the vast semi-arid West. The storms came, generally, first from the southern sector of the Great Plains—the drought-ridden fields of the Texas-Oklahoma Panhandle, western Kansas, eastern Colorado and northeastern New Mexico—and then from the Plains States to the north. Drought and misuse of the land brought the scourge of wind erosion to an enormous total area. Water erosion has seriously affected an additional large area of rolling lands within the plains.

Human enterprise clashed with elemental forces of nature in the occupation of the Plains. That epic story of grass and cattle, of wheat and tractors, of drought and, finally, of dust can not be told adequately within the limits of this paper—but it can be summarized.

II

In the Great Plains, water is the beginning and end of agriculture. Without it there can be no crops, of course—and there also can be no vegetation to anchor the soil against the whirl of wind and the rush of water. Without water, cultivated soil, depleted of binding grass roots and accumulated spongy organic matter, is turned into a dry, powdery substance quite unlike the mellow, granular virgin soil. This powdery stuff starts to blow. Its fine, light particles are lifted into the high pathways of winds and are carried long distances unless rain or snow intercepts them. A residue of the virgin soil is left for the Plains farmer—the coarse material, as a rule, which is much looser, less stable and far less productive than that which is carried away. Drifting with the wind, usually in an easterly direction, this remaining material comes to rest in dunes. Each dune area represents the equivalent of an area of desert sand which will advance upon and at least temporarily cover good land to its lee. It is a constant menace to the land which lies beyond it, in the path of prevailing winds. Even when plants halt their movement, any disturbance of the cover by plowing or overgrazing will set these dunes in motion again.

An example of what happens to certain types of cultivated land under the impact of drought and wind illustrates the process of land decline in the Plains:

[1] Presented in a symposium on the Scientific Aspects of the Control of Drifting Soils. Denver meeting of the American Association for the Advancement of Science.

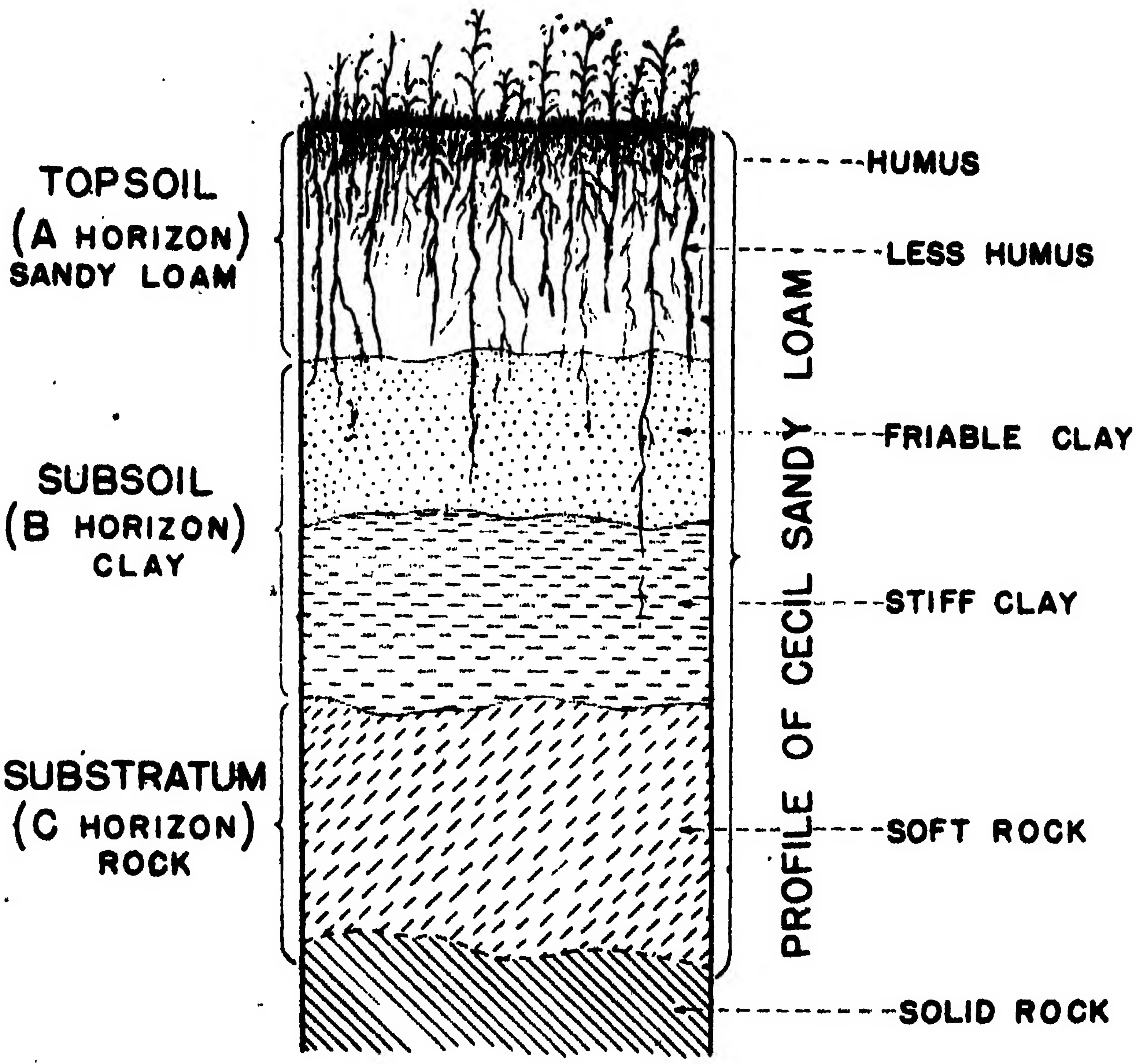

FIG. 1. A TYPICAL "SOIL PROFILE"
SHOWING GRADATION FROM FERTILE TOPSOIL AT THE SURFACE TO SOLID ROCK. SOIL-DRIFT REMOVES THE BEST PART OF THE TOPSOIL, LEAVING INFERIOR LAYERS BELOW IT.

During February, 1937, samples of dust were collected from snow and ice along the pathway of a dust storm that originated in the Texas-Oklahoma Panhandle and traveled across Kansas, Iowa, Minnesota and Michigan into Canada. A composite sample was taken from a small dune formed near Dalhart, Texas, by the storm that brewed this Canada-bound "duster," and another sample was secured from unplowed grassland in that vicinity. Dust collected 500 miles northeast of Dalhart, on grounds of the Soil Conservation Experiment Station near Clarinda, Iowa, contained ten times as much organic matter as the wind-assorted dune sand that was left behind. It also had 9.5 times as much nitrogen, 19 times as much phosphoric acid and 12 times as much fine material in the form of silt and clay. The dust contained 3 times as much organic matter as there was in the grassy soil near Dalhart, 3 times as much nitrogen, nearly 5 times as much phosphoric acid and about 5 times as much fine material. The sample of essentially virgin soil (unbroken grassland with virgin soil profile) contained 79.2 per cent. of sand, while the dune sample, representing what was left after blowing, contained 91.8 per cent. The dust deposited in Iowa contained no particles large enough to rank as even fine sand.

To an alarming extent, therefore, the fertile parts of the soil are blowing away; to an equally alarming extent, menacing, drifting sand is left behind. These evidences of increasing land decline emphasize two acute needs. We must find effective means to prevent, for all time, the breaking-up of any more loose, sandy land in the Plains, and we must turn back to stabilizing cover much farm land that already has been broken.

III

Soil-drift, typified in the results of this storm of 1937, presents three serious menaces. In the first place, it impoverishes fields by stripping the layer of rich topsoil down to depth of plowing or deeper. It also deposits wind-transported, sorted material in mounds of relatively unproductive, troublesome silt and sand. Finally, it threatens to develop great dune areas which may exceed all possibility of practical control. Since 1934, countless small and large dunes have formed on the Great Plains. Some are scattered and incidental; others exceed 1,000 acres in area and 10 feet in height, dominating the landscape of extensive regions. Their spread suggests conditions which prevail in parts of the Sahara border, as Ainslie[2] describes them:

ANALYSES SHOWING THE EFFECT OF A DUST STORM ON SOIL

	Virgin soil in grass near Dalhart, Texas	Sand dune, near Dalhart, Texas: formed during storm of February 6, 1937	Dust deposited by same storm on surface of snow near Clarinda, Iowa, February 8, 1937
	Per cent.	Per cent.	Per cent.
Organic matter	1.06	0.33	3.35
Nitrogen	.06	.02	.19
Phosphoric acid	.04	trace	.19
Potash	2.05	1.77	2.58
Sand	79.2	91.8	0.0
Silt and clay	19.5	7.5	97.0
Ultra-fine colloidal material	8.1	5.2	33.4

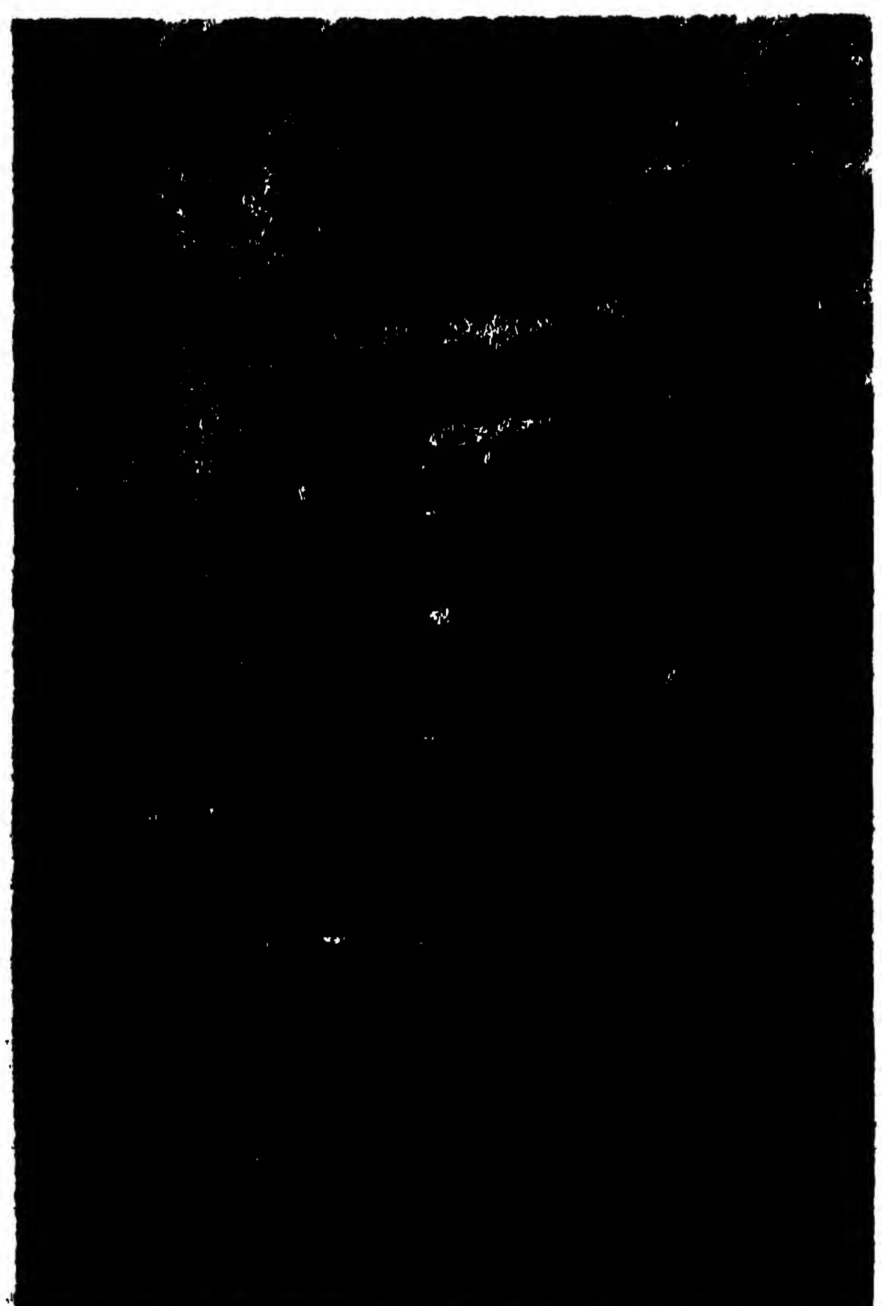

FIG. 2. SOIL STRIPPED TO PLOW DEPTH

BY A SINGLE DUST STORM. EAST-CENTRAL SOUTH DAKOTA.

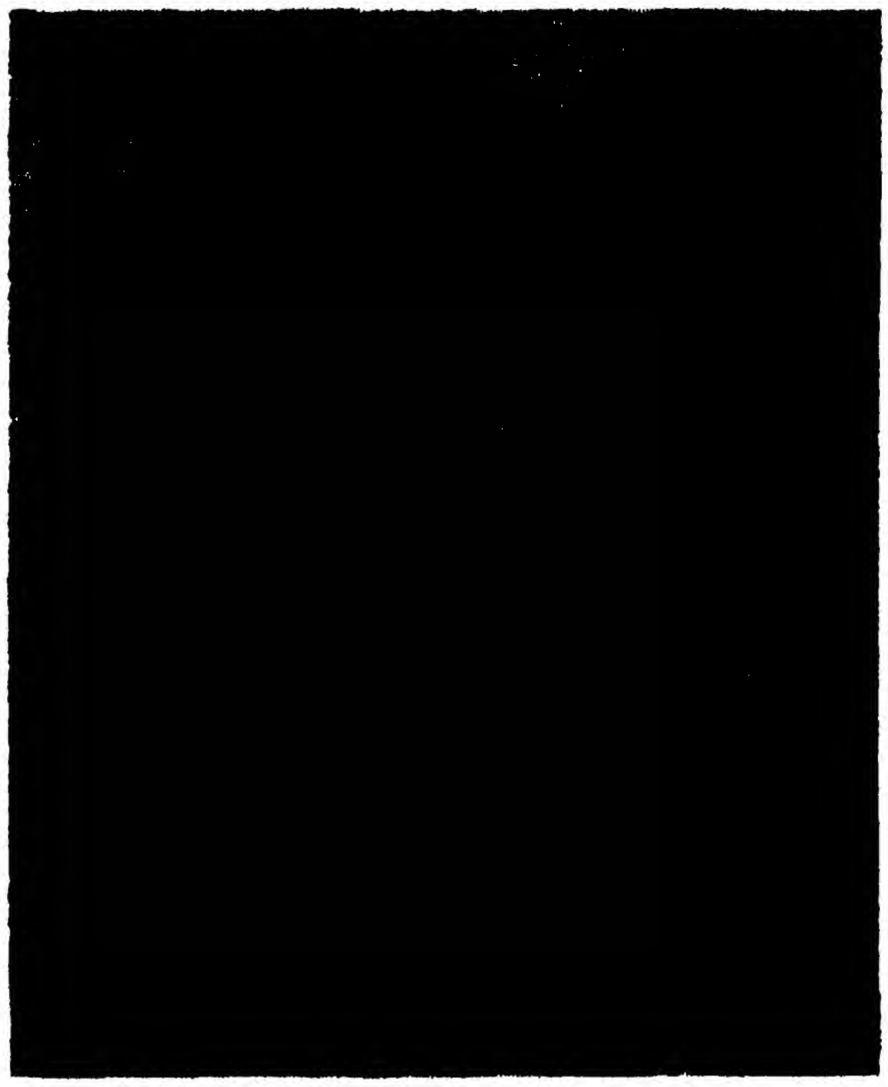

FIG. 3. WIND EROSION ON AN UNPROTECTED FIELD

IT WAS DISKED IN LATE FALL; ALL LOOSE SOIL WAS BLOWN AWAY THE FOLLOWING YEAR.

> A few months ago I had the opportunity of visiting the French Niger Colony lying to the North of the Nigerian boundary; that country is very largely desert and includes within its area probably the most dreaded desert region in the world; nevertheless, throughout the country there are many ruins of ancient towns and villages; it was evidently at one time heavily populated, and so must have been a well-watered region. There are both Arab and French records to show that up to the middle and towards

[2] J. R. Ainslie, "Forests in Relation to Climate, Water Conservation and Erosion." Bulletin 159, Department of Agriculture and Forestry, Union of South Africa.

FIG. 4. ABANDONED FARM
IN EAST-CENTRAL SOUTH DAKOTA, SHOWING DRIFTED AND DEPOSITED SOIL. 1935.

the end of the 18th Century . . . these towns were inhabited by an active farming and trading people; the area, however, became deforested and it has only taken some 200 years to depopulate a country as large as the Union of South Africa. . . . First came the shifting cultivator with his axe and fire; secondly, the grazier with his camels, cattle, sheep and goats . . . and now comes the desert. . . .

If such changes take place on the Plains—if we fail to stabilize the dunes in time and permit them to coalesce and cover townships, counties or groups of counties—no exceptional vision is required to perceive the land anarchy which will follow the probable eastward march of sand across extensive areas of presently productive farms. No one can predict, of course, just how far the dunes may advance with prevailing winds before nature can check them with vegetation. We do know that in the geologic past sand dunes spread almost across Nebraska before bluestem and other plants finally anchored them. And in this connection, it is pertinent, I think, to notice that the Nebraska Sandhills furnish a splendid example of good land use. Most farmers of this region utilize these vegetatively stabilized dunes for moderate grazing, having learned from experience that cultivation or overgrazing immediately starts the sand to drifting.

I believe that Americans, duly aroused, have too much common sense to let soil-drift reach Nigerian proportions, especially since demonstrations have shown that blowing can be largely, if not entirely, controlled by practical farm and range methods and that young dunes can be halted by vegetation. It is true, however, that urgent requests for emergency control come from the Plains region year after year, indicating that temporary measures do not have effects which approximate permanent stability. Danger also lurks in the tendency of Americans to forget evils of the past when better times arrive—to forget during rainy periods the parched fields and grassless ranges, the dust and dust-induced diseases of severe drought years.

IV

When Denver was settled in 1858, a vast sea of grass extended eastward for hundreds of miles, short-grass predominating immediately to the east and beyond it the tall grass of the Plains border and prairies. Herds of buffalo migrated with the seasons from northern to southern pastures. With the coming of white man and the extension of railroads across the plains, these animals were slaughtered in countless numbers; except for local food supply, only their hides, horns, bones and tallow were used. Wanton destruction of the buffalo was a prelude to the land exploitation which followed.

First came the cattlemen. After the Civil War, the central and northern Great Plains were stocked with longhorn cattle from the ranges of Texas, and thousands of animals were driven over long trails to the markets or shipping points of the North and Northeast. Profits were good at first; speculation followed. By 1890, much of the Plains was stocked to capacity and during the five subsequent dry years the range was seriously depleted. Cattle died by the thousands, and investors both in the East and in Europe suffered tremendous losses.

Farmers gradually followed the cattlemen in a large and wide-spread area. As the humid lands farther east were settled, agriculture pushed westward, encroaching on the range despite protests from the ranchers, who temporarily convinced many persons that the Plains were not suited to agriculture. In some localities the land was divided into small farms to preclude speculation, but the 160 acres allotted under the Homestead Act generally were too small to support a family under sub-humid climatic conditions. During periods of heavier than average rainfall, however, farmers forgot past droughts and ignored the limitations imposed upon them by small farms. They often stated, and frequently believed, that "rainfall followed the plow" and that each new mile of railroad con-

FIG. 5. SOIL STABILIZATION BY PLANTING
ON THE SOUTH DAKOTA FARM OF FIG. 4. THIS SHOWS IT IN 1937.

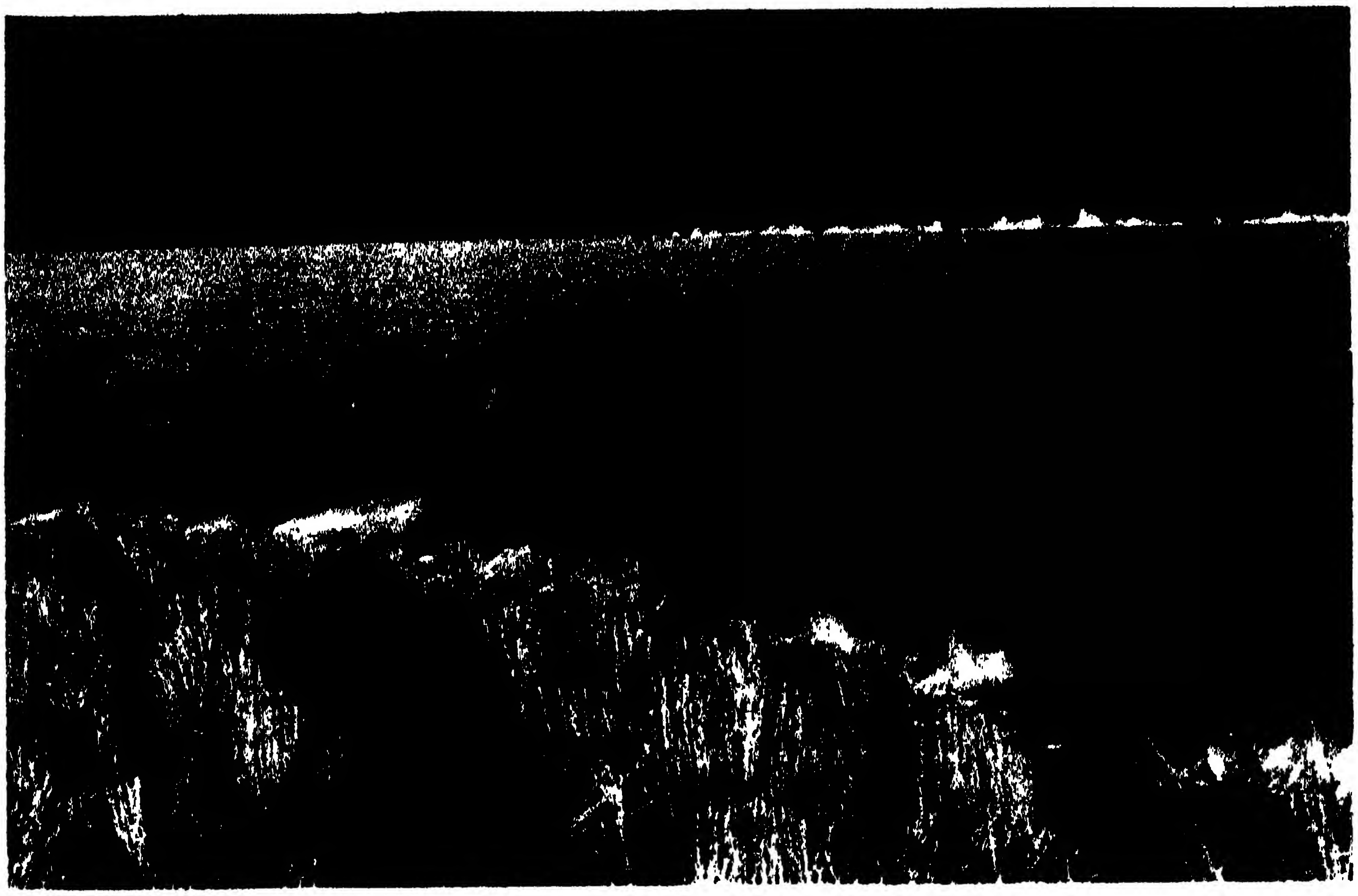

FIG. 6. BURNING STUBBLE IN WESTERN KANSAS
THIS PRACTICE SIMPLIFIES PLOWING BUT DESTROYS NEEDED ORGANIC MATTER.

structed was an added guarantee of moisture. The Timber Culture Act of 1873 was passed in the hope that tree planting also would increase rainfall. Farming steadily moved westward, more and more sod was broken, and the organic content of the soil was dissipated by cultivation and oxidation.

When the sod was first broken, wind erosion was negligible and crops usually were good, but during the first drought thereafter, drifting and dust storms, "sand storms," frequently plagued the West. For more than 50 years individual Plains farmers have faced the menace of recurring drought and wind erosion. Recent dust storms are merely the accumulated result of long-continued exploitation, intensified by an unusually severe and protracted drought.

Most of the Plains was settled so slowly that soil blowing developed gradually, but Oklahoma presents a sharp contrast to this step-by-step progress. Its agricultural development waited until the various Indian reservations were opened to settlement. The land then was taken up rapidly, was cultivated and presented a serious problem of wind erosion within a period of less than 10 years. During this short time the farmers of the then Indian Territory developed through necessity a variety of means for checking soil-drift. Most of them served good purposes in some places and some proved helpful rather generally, yet the problem increased to proportions beyond control by individuals. This rapid development emphasized the relationship between land utilization and the erosion hazard with special clarity.

Soil drift was aggravated by economic necessity. Most of the original homesteaders lacked capital and had to grow cash crops, which usually were conducive to erosion. In periods of drought, crop failures were frequent. When the homesteaders failed, they were followed by short-period tenants to whom immediately profitable harvests also were neces-

sary. Neither owners nor tenants could survive without cheaply produced cash crops.

The hazard introduced by cultivation and destruction of the native sod was increased by climatic conditions. In Oklahoma, as in other sections of the Great Plains, droughts and periods of more than average rainfall recur at irregular intervals. One fourth of the year's precipitation frequently falls in a single month of spring or early summer, and as much as 15 or 16 per cent. of the year's total commonly descends in an hour. Within a single season farmers encounter problems of both water and wind erosion. In general, however, wind erosion is a major menace only in the western part of the state, while water erosion is statewide, though most destructive in eastern and central counties.

Wind erosion attracted attention first because dust clouds were conspicuous. In 1893, when the Cherokee Outlet was opened, incoming settlers were greeted by dust storms which began about September 10 and lasted two weeks. The dust evidently was blown from older cultivated areas beyond Oklahoma, but the storm itself should have served as a warning. Local drifting frequently began within two or three years after the land was plowed, especially where soils were sandy. From the first, warnings were sounded by a few experienced men, but they generally went unheeded. During the period from 1887 to 1901, the rainfall was heavier than average. Dust storms occurred, but they were less frequent, less severe and briefer than they had been. It was said, perhaps facetiously, that the south wind in Oklahoma had been discouraged by not finding dust to stir up and had quieted down. One observer remarked that "winds are becoming as much of a rarity as drought."

During the dry period, of 1901 to 1904, dust storms increased in numbers and

FIG. 7. THIS STUBBLE PREVENTS WIND EROSION

THE FIELD HAS BEEN DEEP-CHISELED, LEAVING PART OF THE STRAW ABOVE THE SURFACE, WHERE IT FORMS AN OBSTACLE TO WIND. BIG BEND SECTION OF WASHINGTON.

FIG. 8. STRIPS OF SUDAN GRASS AND CORN
THE STRIPS OF SUDAN GRASS PROTECT CORN LAND FROM WIND EROSION. TEXAS PLAINS, 1937.

extent, affecting much of the plowed land in western and central Oklahoma. Local soil movement increased to such an extent that the numerous swirls merged into dust storms of large proportions. Farmers who had never before experienced soil drifting began to complain. No longer could the problem be regarded as one to be solved by individuals.

From 1905 to 1908 the rainfall again was above normal and again the reports of drifting decreased, only to be revived once more during the dry period of 1909 to 1914. Drifting soil frequently covered entire fields of growing crops. In addition, the sand blew with such force that it often cut down young plants. A farmer in Major County reported that in three different years his alfalfa crop had been ruined in this manner.

V

Scientists did not wholly ignore the evils of wind erosion. As early as 1900 Professor Ten Eyck described the processes of deterioration which led to widespread soil-drift:

> When the wild prairie is first broken, the soil is mellow, moist and rich, producing abundant crops. After a few years of continuous cropping and cultivation, the physical condition of the soil changes; the soil grains become finer; the soil becomes more compact and heavier to handle; it dries out quicker than it used to; bakes worse. . . . After a soil has been cultivated and cropped a long time, it tends to run together and is very sticky when wet, but when dry the adhesive character disappears almost entirely. The grass roots which formerly held it together are decayed and gone, and now when loosened by the plow it is easily drifted and blown away.

In general, cover crops were regarded as the best means for controlling wind erosion. Various grasses, drought-resistant forage crops and dry-farming cultural practices, such as listing, were used. These did some good, at least locally. Bermuda grass (*Cynodon dactylon*), which was esteemed chiefly for its ability to hold the soil and prevent washing, was used to control both wind and water ero-

sion. Other grasses, such as Colorado grass (*Panicun texanum*) and crab grass (*Digitaria sanguinalis*), were tried. Alfalfa was regarded with special favor because it produced several crops of hay during a single year; but it was difficult to establish. Fall and winter winds often blew the seed from sandy fields; when good stands were obtained, the blowing sands of spring sometimes cut them to pieces. This was overcome, to some extent, by the use of a nurse crop. Many farmers sowed oats or sorghum in the spring and harvested the feed in August, leaving a stubble five or six inches high. Alfalfa was then sowed amid the stubble. The fall growth was usually killed by early frost, but was left standing for protective purposes. Some farmers combined oats with alfalfa in spring planting, but others preferred cowpeas because they both held the soil and improved it. Kafir, sweet clover and even wheat were tried, too. In some places, cropped fields were alternated with fields of native meadow or tame grass. In other regions, 10 rows of kafir were alternated with 10 rows of some contrasting crop.

Dead covers were used, as well as living ones. The farmers of some sections spread manure upon plowed or harvested fields. A smaller number of operators scattered straw and other trash, pressing them into the soil with disks. Stubble proved to be effective and cheap, yet neither it nor the other dead covers achieved general acceptance. The majority of farmers raked together all such litter and burned it, thus both destroying the protective cover and diminishing the humus supply of the soil.

Thousands of forest plantings were made in Oklahoma before 1907, originally in the hope that trees would bring rainfall. By the time that theory was ex-

FIG. 9. WATER AND RANGE-PLANT CONSERVATION
IT EMPLOYS A COMBINATION OF RESTRICTED GRAZING, PONDS AND CONTOUR FURROWING. TEXAS PLAINS, 1936.

FIG. 10. TERRACING ON ROLLING LANDS
CONSERVES WATER AND PREVENTS EROSION OF SOIL. OKLAHOMA, 1936.

ploded, the habit of planting trees was somewhat ingrained, and the use of trees as windbreaks was continued by a considerable number of farmers. Among the trees most used were Russian mulberry, black locust, osage orange and tamarisk. Much care was used in getting the trees started and, later, in cultivating them, but water was not artificially applied. A considerable number weathered the droughts, especially in situations most favorable to retention of rainfall and melting snow.

Cover crops generally were not cash crops, and the latter, as we have said, were necessary to the Oklahoma farmer. The dry farming boom greatly increased the acreage of cultivated plants. Dry farming, introduced at the end of a period whose rainfall was below average and coincident with a period of heavier rainfall, captured the imagination of the Oklahoma farmers and was hailed as the savior of agriculture on the Plains. The decrease in blowing during the second half of the nineties was, to a considerable extent, credited to dry farming, and it was said that Campbell, the method's chief advocate, had proved that drifting soils could be made practically stationary.

Campbell's methods of dry farming, whose principal element was soil mulching by cultivation, is familiar to those who have followed the agriculture of the Plains. In some places the system worked. Its big mistake was the assumption that a single method of cultivation was universally applicable, under all climatic conditions and on all types of soil. When dry periods recurred, blowing was increased, not only because the cultivated area was extended, but because the soil too often was left in a bare and finely pulverized condition favorable to wind movement. Campbell had recommended that the soil when plowed be left in a "small cloddy" condition, but that was impos-

sible on deep, sandy land. Although the system as a whole fell into disuse, certain elements of it continued in general practice and were modified to permit cultivation with a minimum amount of blowing. Deep fall and winter plowing thus persisted, though it was not recommended for loose sandy land. Even on other lands its effectiveness frequently was modified by climatic conditions during the winter. If the season turned out to be relatively wet, fall plowing proved satisfactory. If it did not, danger of blowing increased.

Gradually the lister replaced the turning plow, especially in spring planting. Crops were planted in the furrows which (where they followed the contours) served as reservoirs for rainfall. The intervening ridges made miniature windbreaks and were not entirely dragged down until growing crops protected the soil.

The disk harrow was almost as popular as the lister. Both were originally designed to conserve moisture and both emerged as tools for controlling soil-drift. The disk was used to roughen the soil, as a substitute for a packer, and to press stubble, trash or manure into the ground. In many places the use of the disk temporarily checked blowing, and it was considered the best tool available for that purpose.

During and immediately following the world war, mechanized agriculture developed, spreading rapidly across the Plains. Machines enabled the dry-country farmer to grow wheat at less than half the cost of production in the rougher but more humid lands to the east—at least, in years of favorable moisture. Low costs encouraged land speculation, and enormous new areas were planted to wheat. With the development of labor-saving machinery, farming often became a part-time job. A crop could be planted and harvested in six weeks, and farmers could spend the remainder of the year in other work. With two sources of income, they could

FIG. 11. BASIN-LISTING OF SUMMER FALLOW

ALTERNATED WITH STRIPS OF WHEAT. THE BASINS ARE VERY EFFECTIVE MEANS OF HOLDING RAINFALL. SOIL CONSERVATION PROJECT NEAR RAPID CITY, SOUTH DAKOTA, 1937.

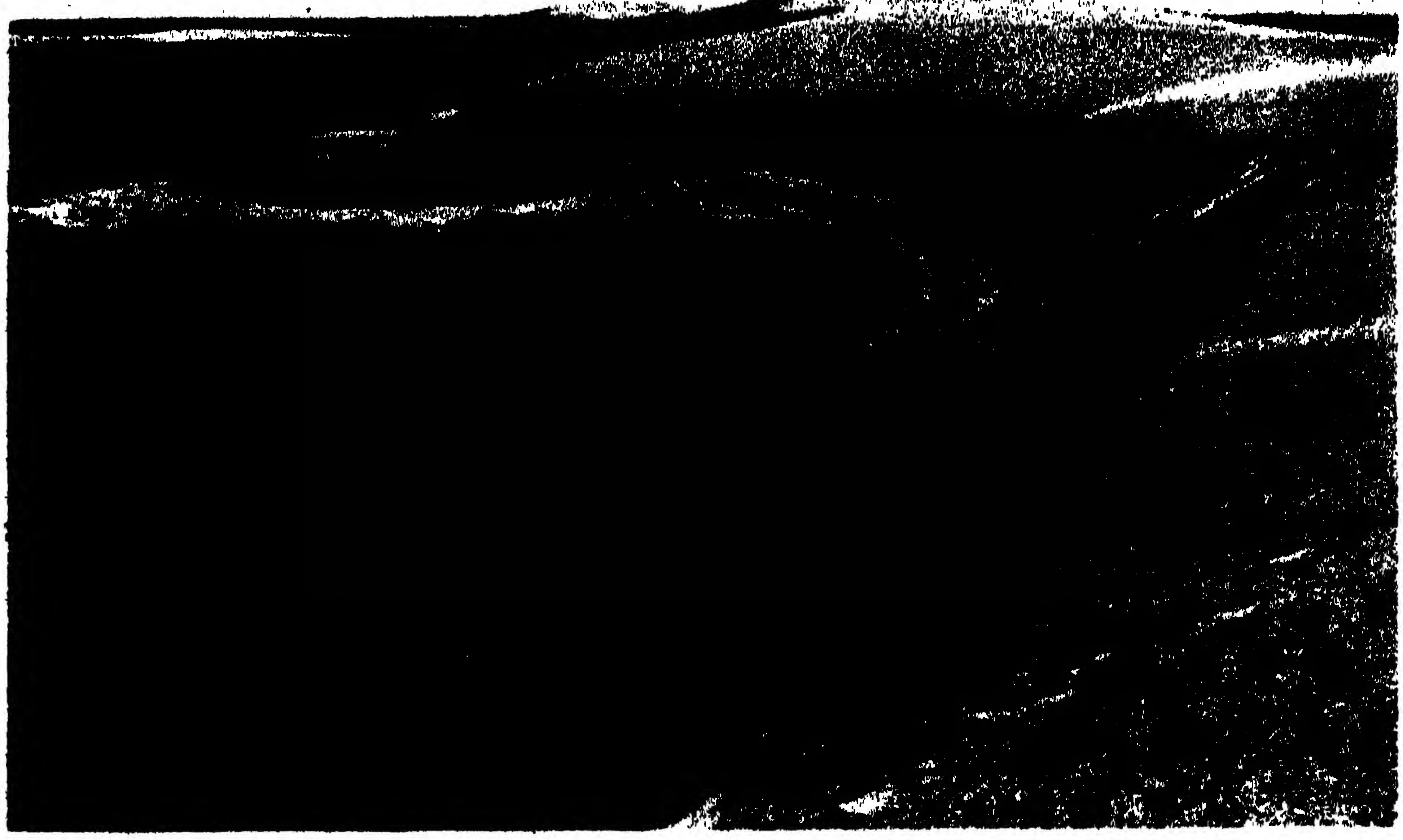

FIG. 12. THESE DUNES ARE COMING UNDER CONTROL
FURROWING OF SPACES BETWEEN THEM PERMITS WEED GROWTH. THE CRESTS HAVE BEEN DRAGGED TO HELP WINDS REDISTRIBUTE THE SAND. DALLAM COUNTY, TEXAS, 1936.

afford to gamble on the weather in areas where full-time farming had not been economically possible.

Between 1920 and 1930, land values fell throughout the country; but in the High Plains of Kansas, Oklahoma and Texas, prices soared and population increased. From 1924 to 1929, crop land in the Great Plains increased by nearly 15,000,000 acres. This expansion was the immediate prelude to the major dust storms which accompanied drought in the '30's.

We have seen how some Oklahoma farmers curbed soil drift, but their example was not widely followed, even in their own state. There was virtually no attempt to develop a coordinated plan of erosion control, involving treatment of the various types of land, existing under different climatic conditions, according to their individual needs and adaptabilities. Some of the measures that were used extensively were improperly used. Listing, for example, was seldom on the contour, except by accident, so that one of its great values was missed, that of conserving rainfall.

In other parts of the Plains, such protective measures as strip-cropping were employed to some extent. On the whole, however, attempts to control erosion were pitifully meager. Countless farmers did nothing to hold the soil or conserve the rainfall. On the other hand, a great deal was done in the opposite direction, such as cultivating up and down the slope, burning or overgrazing crop stubbles, and plowing for seeding at times when the meager content of moisture in the soil indicated little opportunity to produce a reasonable yield.

VI

Emergency measures for controlling wind erosion usually are practiced *after* the soil begins to move. They take effect immediately and afford protection for

indefinite periods, which generally are brief. They consist principally of tillage operations which roughen the surface by listing, pocket fields with hole-digging or basin-listing machines, or which plow up resistant clods from the compact or fine-textured subsurface.

Other control measures include the application of foreign material, such as trash mulch, which is spread over or worked into the soil; off-season planting of cover crops; and removal of barriers likely to cause accumulation of drifts or hummocks. Mulching is rarely employed, because material is lacking. These practices are of emergency character if they are used after erosion actually gets under way, or when it threatens to start at any moment. They produce more lasting results, however, than does strictly emergency tillage.

It is very nearly true in the Plains that so long as the organic content of the soil remains low all agronomic measures for wind erosion control are emergency measures. It is also generally true that only a permanent cover of vegetation can afford more than temporary relief on deep, loose, sandy land and on shallow soil over dense caliche.

Permanent control involves a combination of precautions which will prevent the soil from getting into a condition which favors erosion. For the most part, such precautions are less immediate in their effect, but far more lasting, than those of emergency tillage. Unfortunately, permanent control measures may not take full effect within a year. Nor is every measure included in a permanent system for controlling erosion individually effective over the years. Some, such as contour listing and range contouring, may need to be repeated or re-installed; others, such as retirement of erosive land to permanent cover and the building of dams, are individually planned for permanency. Specifically, permanent control involves: (1) water conservation by detention, diversion and spreading struc-

FIG. 13. DRIFTING SAND AND DUNELETS

THE RESULT OF ONE-CROP FARMING, AFTER THE FARMER WAITED FIVE YEARS FOR A WHEAT CROP, FROM 1932 TO 1936. TEXAS PLAINS, 1936.

FIG. 14. RESTORATION OF A TEXAS FARM
THE CONDITIONS SHOWN IN FIG. 13 WERE QUICKLY IMPROVED BY TERRACING AND CONTOUR TILLAGE, WHICH CONSERVED WATER. SORGHUM THEN WAS PLANTED, IN A SYSTEM WHICH SELECTS THE BEST CROP FOR EACH SEASON. TEXAS PLAINS, 1937.

tures, and by contour-cultivation of fields and contour-furrowing of range land to promote continuity of vegetative cover; (2) the use of protective vegetated strips and borders of grass, crops, shrubs or trees; (3) the adaptation of crops and cultural practices to varying topographic, soil, moisture and seasonal conditions; (4) the conservative utilization of increased organic residues produced by these measures; (5) the retirement of critically erosive areas to permanent vegetative protection; and (6) the proper distribution and regulation of grazing on range lands.

The application of these principles involves the determination of the different needs of individual areas, the selection of a particular device or combination of devices to afford protection within the limitations of a particular tract of land, the selection of a combination of devices to meet jointly the needs of associated areas of land of different characteristics, and, finally, efficient application of the selected devices.

The most wide-spread opportunities for water conservation are to be found in runoff prevention on the heavier soils and diversion of runoff from waste land areas to sites of usefulness. Effective use of vegetation involves conservative regulation of grazing range land, crops and stubble, the prevention of burning of crop residues, the use of tillage methods which allow trash to remain on the ground, strip cropping and protective use of grass for the retirement of critically erosive areas. The greatest chance to use emergency cover crops probably occurs in early or mid-summer when rains are most likely to fall. The best opportunity to utilize border and strip designs is found in sites where waste water can be utilized in the support of windbreak tree plantings, and in fields

where the erosion-inducive or clean-tilled crops are grown or summer fallow is practiced. Emergency tillage operations are most likely to be needed in bare or thinly vegetated fields and in places where neighboring lands have been permitted to reach a condition which favors excessive blowing. In every case, when we apply these measures, we must determine what combination of methods is most economical and effective. Very rarely can we achieve adequate control by using a single method.

The ability of an economical combination of methods to effect reasonable control should determine changes in land use. For example, soils too sandy, too shallow or too infertile to permit economical maintenance of adequate vegetative cover from the residues of annual crops must be retired from cultivation and turned into grassland if adequate erosion control is to be achieved.

With proper land use and normal soil stability, emergency control measures should rarely, if ever, be needed. Farmers, facing the problem seriously for the first time, have found that they need emergency measures for temporary respite, or until opportunity permits something more lasting. In such circumstances, emergency methods are the first step toward permanent control.

Unfortunately, however, the magnitude of the immediate emergency problem in the most seriously affected areas has partly obscured the need for permanent control through a far-sighted precautionary program. Also, such repair work as the leveling of soil drifts and hummocks has been looked upon as final. These efforts are worse than useless, however, unless steps are taken to prevent recurrence of troublesome drifts. Indeed, this may be said of all emergency control.

It is hard to avoid the conclusion that unless vigorous steps are taken to effect permanent control, emergency efforts can not long be justified. The fallacy of reliance on temporary methods alone has

FIG. 15. CLODDY PLOWING IN A WIND-EROSION AREA

A MEANS OF HOLDING SOIL AND HALTING THE DEVELOPMENT OF SAND DUNES. DALLAM COUNTY, TEXAS, 1937.

FIG. 16. LISTING TRAPS WIND-DRIVEN SAND

FURROWS AND SPACES BETWEEN THE CLODS ARE FILLED WITH SAND, WHICH HAS SPREAD FROM THE DUNE THAT COVERED THE BARE MIDDLE GROUND. THIS AREA WILL BE DRILLED TO ROW CROPS DURING THE NEXT PLANTING SEASON. DALLAM COUNTY, TEXAS, 1937.

been amply demonstrated in many parts of the Plains during the recent long drought. The fact that farmers have been unable to control the situation with these temporary measures shows the need for a coordinated permanent program, which, properly directed and extended, will prevent recurrence of conditions now spreading in many localities.

VII

Recent studies by C. W. Thornthwaite,[3] of the Soil Conservation Service, indicate that the nature of the wind, as well as the physical characteristics of the soil, is important in the development of dust storms. Soil conditions favorable to blowing may exist for long periods, but unless atmospheric conditions produce wind velocities sufficient to transport the soil, no movement will take place.

The amount of soil transported and the distance to which it is carried depend on the detailed characteristics of atmospheric circulation. The wind is not a steady current of moving air. It comes in a succession of gusts and lulls which continually vary in direction, even though their average value may be maintained for hours at a time. This lack of uniformity comes from friction on the ground, which gives rise to eddies and whirls which resemble the eddies and whirlpools formed in rocky streams. Thus the great dust storms, such as the one of May 12, 1934, which darkened the sun over Washington, D. C., and extended beyond the Atlantic coast (the first event of that kind since white men came to America), grow from an enormously large number of little dust whirls blown up by gusts of wind passing over dry, loose soil.

When a current of air of one type replaces one of another type a considerable

[3] C. W. Thornthwaite, "Life History of Rainstorms." *Geog. Review*, 27: 92–111, 1937.

change in wind direction and velocity may take place within a very few minutes. On the other hand, large masses of air, many hundreds of miles in extent and frequently four or five miles deep, display great areal or horizontal uniformity in both temperature and humidity. Their principal characteristics are developed in regions over which they originate or remain for some time during their passage around the earth. Air-masses reaching the United States from northern Canada are cold and dry and are called Polar Continental; those arriving by way of the North Pacific Ocean are cold and comparatively moist, and are designated as Polar Pacific; those which come from the Gulf of Mexico and the tropical Atlantic Ocean are warm and very moist and are called Tropical Marine air masses. These are the three principal types of air which are involved in determining the daily weather and the climate of central United States.

Dust storms seem to be most frequently associated with Polar Pacific air masses. This type of air is characteristically turbulent; that is, there are many small vertical and horizontal currents within the large mass. These give the wind power to lift particles off the ground and to carry them along the surface or even into high air strata. In most of the dust storms that have been studied, the dust cloud developed with the arrival of the Polar Pacific air and lasted as long as this type of air remained. In many cases the storm ended as abruptly as it started, stopping when a Polar Continental air mass entered the dusty region. Polar Continental air lacks the turbulence of Polar Pacific air; it is cold and dry, and its ability to "clear the atmosphere" is due to its stability or lack of small vertical currents, even though its horizontal wind velocities often exceed those observed in the Polar Pacific air.

Wind velocities, especially in the upper air during dust storms, are often exceedingly high, as was shown by a storm in the latter part of February, 1936. This storm picked up soil from the northern Great Plains, carried it aloft, and in 25 or 30 hours transported it 1,500 to 2,000 miles to New England, where it returned to the earth with precipitation. During the dust storm of November 12 to 13, 1933, the wind at the surface reached velocities of 45 to 55 miles per hour at many places in North and South Dakota.

Dust storms, however, are only extreme manifestation of moving air's ability to lift and transport soil. Soil drifting may occur in any type of air whose surface layers have sufficient turbulence to pick up grains of silt or sand. Thus, Tropical Maritime air is usually quite unstable because of its high moisture content and temperature, or Polar Continental air, which has become warm and moist during its passage southward across the continent, may have enough lifting power to cause considerable soil-drift.

There is no other part of the interior United States in which average wind velocities are as high as they are on the Great Plains. Throughout most of the area, velocities average 10 to 12 miles per hour, but they reach 16 to 18 miles per hour in the Panhandles of Texas and Oklahoma and in the eastern Dakotas. Not only are averages high; throughout most of the Great Plains monthly variation is great. The highest velocities prevail in winter and spring, when the soil moisture is most frequently depleted and when the ground is bare and likely to be in the process of cultivation.

There is also a diurnal variation in wind velocity, which is pronounced except when it is obscured by the winds associated with the changes in type of air mass occupying given areas. Usually the wind velocity increases about two hours after sunrise and reaches a maximum about three o'clock in the afternoon. Some of the most severe wind erosion areas of the Dakotas and of the Texas-Oklahoma Panhandle are the very areas which have the

highest average wind velocities at three in the afternoon.[4]

I have mentioned these climatic relationships to indicate the complexity of the problems involved in control of wind-erosion and to emphasize the fact that we do not know all that we should about the numerous variables. We are studying them individually and collectively, with the hope that we may discover clews to new control devices and improve old ones.

VIII

In its demonstration projects and CCC camp work, the Soil Conservation Service is applying to the land in various parts of the Plains a coordinated program of soil and water conservation. It is using all known practical measures as rapidly as they can be fitted into the working plans to meet the diverse physical conditions of the land, the climatic environment and the economic situation. Such a program can not be carried out in all localities at a single stroke; but, as nearly as it can be done, this is the aim of the Service.

Several social and economic adjustments beyond the scope of the Soil Conservation Service program must be made in some localities. They include retirement of large blocks of unfavorable land from crop use, changes in the size of farms and ranches, improvement of the credit and tax situation, and the finding of more favorable lands for misplaced farmers.

The actual working procedure of the Service is based on detailed surveys indicating the kind of soil, the slope of the land, the degree of erosion, the vegetative cover and the present use of the various component parts of a farm or other operating unit. This means that for every area treated a blueprint and work plan are developed in advance. Then the Service applies a fully coordinated program of husbandry, involving the conservation of as much of the rainfall as possible.

The results obtained thus far have been decidedly encouraging. On some projects, virtually all the rain falling on fields and pastures has been directed into the reservoir of the soil by practical farm and ranch devices, while much or all of that which normally runs to waste down roadside ditches has been directed to useful purposes by diversion into fields or onto grass lands. This conservation of water has given great help to both established stands and new growths of protective vegetation, which are essential to effective control of blowing.

Conservation of water in small ponds for use of stock and man, as well as small-scale irrigation in favorable situations, also has been effectively fitted into the regional program. Surveys show that there are thousands of places where water now running to waste can be ponded or can be so diverted and spread as to perform good service.

A single erosion-control and water-conservation project illustrates the type of land treatment which the Soil Conservation Service carries on in various areas throughout the Plains. This is the Smoky Hill project, located in Cheyenne County, east-central Colorado. It comprises 160,000 acres of intermingled range and farm land, most of which has suffered in various degrees from wind erosion through the recent prolonged drought, many places having lost more than 6 inches of soil. Numerous bare areas have been cluttered with hummocks and dunes of accumulated wind-blown soil, necessitating extensive leveling operations before effective contouring and other necessary types of control work could be put into effect. Water erosion also has damaged much sloping land. The most severely affected land is that which at one time or another was cultivated. Over-

[4] C. Goodrich, *et al.*, "Migration and Economic Opportunity." Chapter 5 in "The Great Plains," by C. W. Thornthwaite. Philadelphia, University of Pennsylvania Press. 1936.

grazing has been a contributing factor, but it has not caused nearly so much damage as the plow.

The most important task was the conservation of enough moisture to supply a protective cover of vegetation. In the main, this has been accomplished by contour furrowing and terracing of grazing land by contour-listing and terracing of farm land. Thus far, these measures have held all the precipitation, and have distributed it so well that vegetation has begun to grow again over most of the 40,000 acres in which operations have been about completed. Most of the treated land has been fenced in order to control grazing. Much seeding has been done, many critical slopes have been subsoiled on the contour, dams to spread water or hold it for use by stock have been installed in favorable situations, and various other water-control measures and soil-holding farm practices have been installed or inaugurated. A highly important element of the program has been the retirement of critically erosive areas to the permanent protection of vegetation. As a result of these intensive methods, adjusted to diversified land conditions, comparatively little of the treated area is in a seriously blowing condition.

If farmers and ranchmen will carry on with these practical operations, and adjust themselves to a type of agriculture based largely on livestock, with a comparatively small area devoted to crops which are used chiefly for supplemental feed, accelerated erosion can be controlled in this part of the Plains. Moreover, a comfortable living can be earned from 3 or 4 sections or a little more, depending on the condition and quality of the land. On the other hand, there is every indication that any considerable departure from such a general plan of land utilization must lead to human poverty, as well as the eventual ruin of a large part of the Plains.

Success in the Smoky Hill Project and many others convinces me that we can protect the Great Plains and continue to use a large part of it for ranching and farming purposes, if we will. Many areas, to be sure, must be retired and turned into grazing reserves, protective grass areas and wild-life preserves, but this procedure also is needed in many other regions. The various grasses of the Plains must be brought into nurseries and cultivated to determine their practical possibilities as agents of conservation. Plant breeding must be carried on with the more promising native grasses, as well as with exotics.

By cooperating with nature, treating the land according to its needs and adaptability, conserving rainfall and making every possible use of vegetative measures of control, we can solve the Great Plains problem. This, of course, demands a permanent program, rather than dependence upon temporary measures which at best can only delay real achievement. The longer we delay permanent solution of the problem, the more difficult and costly it will be for either ourselves or our descendants to save and use the Great Plains.

ANIMAL PARASITES TRANSMISSIBLE TO MAN

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Introduction

Practically all vertebrate animals serve as hosts to parasites, and *Homo sapiens* is not an exception to this general rule. Actually man is an excellent host for various protozoan, helminth and arthropod parasites, the species adapted to live on or in human beings totaling several hundred. There is hardly an organ, tissue or cavity in the human body that is immune to the attacks of one kind of parasite or another. Such vital organs as the liver, spleen, lungs, heart, brain, eyes, and others too numerous to mention are susceptible to invasion by parasites that are capable of inflicting serious damage to the parts of the body that are invaded.

Human beings acquire parasites through some form of contamination, usually traceable to soil pollution, through the consumption of raw food of animal origin, and in other ways. In parts of the world where sanitation and hygienic standards are far below the levels that are accepted in most civilized countries, parasites that are acquired through contaminated food and water constitute an important health factor; in tropical countries they are usually one of the most important health factors. In countries where the level of sanitation is high and where the standards of hygiene are exacting, parasitism that spreads ordinarily through soil pollution tends to disappear, more particularly in urban communities. In rural sections, however, including those of this country, there is always a greater or lesser residuum of parasitic infection of one kind or another, and urbanites who visit the country for rest and recreation may acquire a few unwelcome guests, such as hookworms, ascarids, whipworms, dysentery-producing amoebae and other parasites, which occur as infective eggs, cysts or larvae in contaminated soil.

By and large, however, human beings living in cities and towns are in most cases adequately protected from acquiring parasitic infestations to which rural inhabitants may be exposed as a result of contact with the soil. The nation-wide campaign against soil pollution, undertaken in this country on a large scale in the beginning of the twentieth century, has done much to reduce the danger of acquiring parasitic infestations, even in rural areas. Several years ago the annual report of the Rockefeller Foundation contained the statement that hookworm disease, for years an important factor in the physical and mental retardation of the population of rural areas in certain parts of the South, had been practically eradicated. While this statement was open to challenge at the time that it was published and was challenged vigorously, the fact remains that the hookworm incidence and intensity in the United States have been greatly reduced, thanks to the activities of such agencies as the U. S. Public Health Service, the Rockefeller Foundation, the state boards of health and local health units in the South.

While progress in the control of human parasitic infestations traceable to soil pollution has been steady and on the whole satisfactory, that relating to the control of parasites of man that are acquired from consuming animal food still leaves much to be desired. Actually, the available evidence shows that one human tapeworm infestation acquired from certain species of fresh-water fish is spread-

ing in the United States, although its distribution is still rather limited. Trichinosis, a serious, painful and sometimes a fatal disease of man, is apparently gaining headway. Whether the increase in the number of cases of human trichinosis is only apparent because of the greater vigilance on the part of physicians in making a correct diagnosis, or whether the increase in the number of such cases is real, is difficult to determine on the basis of available evidence. The extent of beef tapeworm infestation, in so far as this can be determined from the data on the prevalence of the larval stages of these parasites in cattle slaughtered under federal inspection, shows that during the past ten years or so this parasite has been holding its ground, although the data of previous years showed a downward trend.

The parasites mentioned, namely, the fish tapeworm, the beef tapeworm and trichina, are the most important parasites of man in the United States that are transmitted through the consumption of animal food. The pork tapeworm, though only of slight importance in this country, must be added to the list. We shall briefly consider each of these parasites and its bearing on human health.

The Fish Tapeworm

The so-called fish tapeworm, *Diphyllobothrium latum*, is really a human tapeworm that spends part of its early life (plerocercoid stage) in certain species of fresh-water fish. According to Wardle the following species of fish in North America are known to be intermediate hosts of the tapeworm under discussion: Pike, *Esox estor;* pickerel, *Stizostedion vitreum*; sauger or sand pike, *Cynoperca canadense*; and perch, *Perca flavescens.* Prior to getting into fishes this parasite occurs as a larva in fresh-water copepods or so-called water fleas, that constitute a part of the microscopic and near-microscopic aquatic life—plankton—which is an important item in the food of fishes. The life cycle of the tapeworm is rather complicated and is briefly as follows:

The tapeworm, which may attain a length of about twenty-five feet and, in exceptional cases, a length of sixty feet, in the human intestine, produces eggs which are microscopic in size and which are eliminated from the ripe or gravid tapeworm segments into the lumen of the host's intestine. Occasionally long chains containing as many as one hundred or more segments may be passed with the excreta of infested animals, including dogs, cats and wild carnivores, such as bears and foxes, that also serve as hosts of this tapeworm. The tapeworm eggs passed with excreta and those which become liberated from the passed segments, as a result of the disintegration of the latter, hatch in water following their normal development. The newly hatched larvae, provided with cilia, may be swallowed by copepods which are usually found teeming in fresh-water lakes. When swallowed by suitable intermediate hosts the larvae undergo further development but do not become infective to man and other definitive hosts unless they reach the body of a second intermediate host, namely, a suitable species of fish, as already noted, and develop there to the plerocercoid stage that is infective to mammals. Fishes become infested by swallowing the infested copepods, and human beings acquire the fish tapeworm as a result of eating raw, or nearly raw, or cold-smoked or salted fish that harbors the stages of the parasites infective to man.

According to Magath the Finlanders, as well as other northern Europeans in Minnesota, have retained their native fondness for raw fish, and the more nearly raw the fish is the better the Finlanders like it. Magath makes the following statements: "One Finlander

remarked that he was in the habit of not carrying a luncheon on a fishing trip, being satisfied with the raw fish he caught. A common dish is fish which has been salted in brine for twenty-four hours and cut up with green peppers, cabbage and cucumbers, while some bury the raw fish for a few days to ripen it, then eat it with salt."

At one time there was considerable discussion among parasitologists as to whether the fish tapeworm could complete its life cycle in North America, some investigators taking the position that infested persons in this country must have acquired this parasite abroad. It has been definitely established, however, that the fish tapeworm has become endemic in North America and many cases of infestation of native origin have been traced. Fishes from the Great Lakes region of the United States have been found to be naturally infested, and species of copepods that are capable of serving as the first intermediate host have been shown to be susceptible to experimental infection. Thus, the entire life cycle of this tapeworm can take place in North America, and this parasite, originally introduced into this country by immigrants from northern Europe, is now definitely established in the United States. According to Ward the belt of infection stretches across the Great Lakes, includes the upper Mississippi basin, even reaching out into Iowa, crosses the height of land into Manitoba and embraces lakes almost to the Rockies.

Once having gained a foothold, it is easy to see how this parasite established itself solidly, since untreated sewage from cities and towns is commonly emptied into lakes. Infested immigrants coming to North America from countries along the shores of the Baltic and from other areas where this infestation is common, polluted the lakes in some of our North Central States and other regions.

In parts of Scandinavia, Finland, Russia and Germany, bordering on the Baltic and connecting waters, the local population shows an incidence of infestation up to 50 per cent. or more. Even a few infested immigrants could have greatly polluted our fresh-water lakes, since it has been estimated that an infested person may discharge at least one million tapeworm eggs a day. The fondness of certain people of European origin for raw fish, or portions thereof raw, or lightly salted or pickled, has served to propagate this infestation in this country. The susceptibility of the dogs, cats and various wild carnivores to this parasite has added a further complication tending to increase the spread of this tapeworm.

Persons infested with the fish tapeworm may exhibit nervousness, loss of sleep, experience creeping feelings and occasionally show a voracious appetite. The symptoms manifest themselves particularly after a person discovers that he or she is infested, this indicating that the symptoms, at least in part, are probably mental rather than physical. Of special interest in connection with this parasite is the occurrence in a very small percentage of infested persons of an anemia that is indistinguishable from pernicious anemia. However, precise information is still lacking with regard to the causal relation of the parasite to the cases of pernicious anemia observed in infested subjects.

The prevention of infestation with the fish tapeworm is simple and absolutely effective. Fresh-water fishes should not be eaten raw, semi-raw, cold-smoked or lightly cured in salt. Thorough cooking of fish is an absolute prevention and can be relied upon as being a one-hundred per cent. prophylactic measure.

The Beef Tapeworm

The beef tapeworm, *Taenia saginata*,

occurs in its adult stage solely in the human intestine where it may attain a length of about thirteen to forty feet. Usually an infested person harbors but a single tapeworm, the occurrence of one worm in the intestine apparently excluding others from developing.

The life cycle of the beef tapeworm is similar to that of the fish tapeworm, except that but one intermediate host, namely, a bovine, is required. Human beings become infested solely as a result of eating raw or rare beef containing the larval stage of the tapeworm infective to man, and cattle become infested with the larval or cystic stage as a result of swallowing the tapeworm eggs with feed or water that has become contaminated in one way or another with the excreta of a tapeworm carrier. The life history of the beef tapeworm involves, therefore, an alternation between two hosts, man and the ox.

Ransom pointed out years ago that a single individual with a tapeworm is a peripatetic center of infection. Each gravid segment of a tapeworm contains several thousand eggs, and several segments may become gravid and expelled every day during a period that may extend over several years. Thus hundreds of cattle might become infested from a single tapeworm carrier, if this person happens to live in a rural district where cattle are raised.

The control of infestation of cattle with the larval stages of this tapeworm will inevitably result in the control of the beef tapeworm infestation in man, and *vice versa.* Reduced to simple terms, improvement in conditions as regards the disposal of human excreta in rural sections will prevent cattle from becoming infested, and this in turn will tend to reduce and ultimately eliminate the infestation in man.

As an example of the unsanitary conditions that prevail in some rural sections of the United States, particularly as regards the disposal of human excreta, an outbreak of larval tapeworm infestation in cattle, technically known as cysticercosis, was investigated by the Bureau of Animal Industry a number of years ago with the following results:

Following the detection under federal meat inspection procedure of a heavy infestation of cysticercosis in 3 lots of cattle which came from the same locality, 105 out of 523 cattle, or 20 per cent., being infested, it was determined that about 1,500 cattle, of which the 523 were a part, had been fed during the winter and spring in the yards of a cottonseed oil mill. These animals were later marketed at various live-stock centers and data were obtained on the 523 animals already referred to. The remaining animals were not traced to the point of slaughter.

The investigation made at the yards of the mill disclosed that the regular water supply for the cattle was taken from a river 75 yards below a sewer outlet. The river was wide and shallow, had a sluggish current, and the banks, which formed a portion of tract of land designed for a public park, were strewn with human feces. The investigation disclosed further that the cottonseed hulls used for feeding the cattle were stored in a building where tramps commonly slept during the feeding season. Evidence was obtained which indicated that the cottonseed hulls had become more or less contaminated with human excreta, the hull house being used evidently by the tramps and mill employees as a place for defecation, especially during very cold weather. An inspection of the 3 outhouse toilets intended for the use of the mill employees showed that the structures were of poor design, the excreta falling directly on the ground or in boxes set on the ground level. As many of the mill employees using these outhouses were transients, it was estimated that about 200 persons used the three poorly constructed and unsanitary outhouses dur-

ing the cattle feeding season. At the lower end of the feed yards there was a stagnant pool which drained a watershed that included a portion of the town and cottonseed oil mill with its three primitive outhouses. The cattle were occasionally forced to drink from this stagnant pool as a result of frozen pipes which shut off the regular water supply. The 1,500 cattle fed at the yards were therefore exposed to the following sources of infection with tapeworm: (1) The outhouses which drained into the stagnant pool; (2) the regular water supply from the sewage-laden river; (3) the cottonseed hulls, which were more or less subject to contamination, and (4) a portion of the town's waste which drained into the stagnant pool. That fully 20 per cent. of the cattle that were fed under these unsanitary conditions became infected, as shown by the data obtained, is not surprising considering the four possible sources of infection.

Two recent outbreaks of cysticercosis in cattle, investigated by the Bureau of Animal Industry, showed conclusively the important role of a single human tapeworm carrier as a spreader of this parasitic infestation to bovines. The facts in these cases are as follows:

Following the receipt of information that 166 out of 252 cattle carcasses were retained in an officially inspected establishment at Fort Worth, Texas, because of infestation with tapeworm cysts, an investigation was made of the premises where these cattle had been fattened for market. It was determined that the bovines in question were kept in a feed lot to which feed was hauled by an individual who later was found to be responsible for the outbreak of cysticercosis. When the owner of the cattle was informed of the retention of a number of beef carcasses, as already noted, from the particular lot of cattle in question, all men on the ranch that were connected in one way or another with the feeding of these animals were examined by a physician, and the individual referred to was found to be infested with a tapeworm. According to the information furnished "about 20 feet of tapeworm" were removed from the person following the administration of a taeniacide. Upon being questioned, the tapeworm carrier admitted that he did not like cooked meat and, therefore, "ate all his meat raw."

The premises to which this and other persons connected with the feeding of the cattle had access had no toilet facilities, and the infested person was seen, on numerous occasions, to defecate in the feed troughs.

In an officially inspected establishment in Oklahoma City, Oklahoma, twelve out of thirty-seven cattle carcasses were retained recently because of infestations with cysticerci. In tracing the origin of these cattle, it was determined that they came from a farm that had no toilet facilities, the barn and chicken house being used as places for defecation by a man and his wife who had charge of the cattle-feeding operations. The only source of water supply for the cattle was a small pond located about a hundred yards from the farm house; all the drainage from the dwelling, barn and chicken house ran directly into this pond. Through the assistance of the State Board of Health, it was determined that the wife of the cattle feeder, who complained of being sick, was infested with *Taenia saginata*. Considering the primitive conditions under which this couple lived, it is not surprising that one third of the cattle that were fed on this farm became infested with tapeworm cysts.

While the consumption of raw or slightly cured fish will probably strike the readers of this article as a freak habit of certain northern European immigrants, the consumption of raw and rare beef is certainly a well-established American custom. Steaks cooked rare

are frequently raw in the middle, and rare roast beef is certainly a common American dish. It is not surprising, therefore, that infestation with the beef tapeworm is quite common in the United States. No adequate statistical information is available on this point, since there is no agency in the United States for collecting this sort of information. Several physicians with whom the writer of this paper has discussed this point stated that cases of human tapeworm infestation are encountered by them, sometimes several times a year in routine practice. That tapeworm infestation in man is not more common in this country is due entirely to the protection that is afforded to the consumer by the vigilant federal meat inspection service and competent state and local meat inspection units.

Beef tapeworm infestation in man occurs in all parts of the world where beef is used for food. In Abyssinia, where beef is regularly eaten raw, practically the entire population is infested; in certain parts of Syria, one third of the population is infested. In countries where beef is commonly cooked the extent of the infestation is more limited.

Under federal meat inspection beef carcasses showing an excessive infestation with tapeworm cysts are not passed for human food, thus cutting off the most fertile source of infection. During the past five years, the total number of beef carcasses condemned on account of tapeworm infestation was somewhat under 1,000 out of a total of over 50 million cattle slaughtered under federal inspection. During the same period, however, over 135,000 beef carcasses were retained on account of infestation with tapeworm cysts. Under federal meat inspection the retained carcasses which contain only one dead and degenerated cyst are passed for food following the removal of the cyst and adjacent parts, and a careful inspection to make sure that no other cysts are present; carcasses showing a moderate infestation are not passed until after the removal of all visible cysts and subsequent refrigeration of the carcasses for a period of not less than six days and at a temperature definitely known to be fatal to the vitality of these parasites, or such carcasses are cooked at a temperature that is known to be destructive to the vitality of these tapeworm larvae. Carcasses showing a heavy infestation, or a pathological condition of the muscles indicative of such infestation, are condemned.

It should be borne in mind, however, that only about two thirds of the food animals slaughtered in the United States are subject to federal inspection, the remaining third being slaughtered in many cases under no inspection or under imperfect inspection. Slaughtering done on the farm for home consumption is not, of course, subject to any official inspection. Actually, however, even the best kind of inspection can not guarantee perfect results so far as the detection of tapeworm cysts in beef is concerned, because in most cases the degree of infestation is slight and a large proportion of slightly infested carcasses necessarily escape even the most careful inspection. The actual number of cases of infestation in cattle with larval tapeworms is probably much greater than that shown by the figures cited. From a practical viewpoint, however, it seems scarcely possible to effect a more thorough inspection for tapeworm cysts than is done under existing requirements. The inspection that is made eliminates most of the carcasses that are likely to transmit tapeworm infestation to human beings; the carcasses that are passed without detecting these parasites probably have only slight or almost negligible infestations.

As in the case of the fish tapeworm, the beef tapeworm in many cases may produce no noticeable symptoms. This

is particularly true of cases involving robust individuals. Delicate and nervous persons and children may show, at times, rather alarming symptoms, including severe gastro-intestinal disturbances, nausea and vomiting. Nervous persons may show convulsions and even some severe reactions that are suggestive of epilepsy. Sometimes tapeworm infestation gives rise to emaciation and anemia. On the whole, tapeworm infestation does not produce serious illness, the severe symptoms mentioned being the exception rather than the rule. Effective treatments for the removal of tapeworms from man have been established, and persons affected should seek the advice of a physician.

Prevention is simple and effective. To avoid tapeworm infestation cook beef until it is well done.

The Pork Tapeworm

Aside from being somewhat shorter, as a rule, the pork tapeworm, *Taenia solium*, bears a very close resemblance to beef tapeworm. Like the beef tapeworm, the pork tapeworm lodges in the small intestine of human beings, its head being provided with hooks that afford the possibility of a firmer anchorage to the intestinal wall than in the case of the beef tapeworm, which lacks this armature. Ordinarily the pork tapeworm is from about two and one half to five feet long, but it may attain, at times, a length of about twenty-five feet. Its life cycle is essentially similar to that of the beef tapeworm, except, of course, that the hog serves as the intermediate host. Human beings become infested with the pork tapeworm by swallowing infested raw or insufficiently cooked pork, and hogs in turn become infested with the cystic stage by swallowing feed or water that has become contaminated with human excreta passed by infested persons. The life history of the pork tapeworm thus consists in an alternation between two hosts, man and swine. The reduction in the incidence of infestation in swine necessarily leads to a reduction in the incidence of infestation in man, and *vice versa*.

Actually the pork tapeworm is very rare in man in this country; the rarity of this parasite in human beings is directly correlated with the rarity of the cystic stage in swine. This is a very fortunate situation, because from the view-point of its bearing on human health, the pork tapeworm is far more dangerous than the beef tapeworm. So far as the production of intestinal disturbances and nervous symptoms in infested individuals is concerned, the two species under consideration are on a par. Unfortunately, however, man is also capable of serving as an intermediate host of the pork tapeworm and thus becoming infested with the cystic or bladderworm stage. Since the cysts may lodge in such organs as the heart, the brain and the eye, an infestation in man with the cystic stage of pork tapeworm may lead to serious consequences and often does. Persons harboring the pork tapeworm in the intestine might accidentally contaminate their hands with the tapeworm eggs. It requires but little imagination to see how the hands thus contaminated might transfer the eggs to mouth and thus pave the way for an infection of the muscles and of such vital organs as the heart, brain and eyes. Several years ago a medical officer of the British Army reported the pork tapeworm as a rather common cause of epilepsy in British troops returning from abroad, presumably from places where the cystic stage of the pork tapeworm was of rather common occurrence in swine, the epileptiform symptoms being due, of course, to the lodgment of the cysts in the brain and other parts of the central nervous system.

Under federal meat inspection swine carcasses showing a light infestation with tapeworm cysts are passed for sterilization, which means thorough cooking at a temperature more than adequate to destroy life in these parasites; if the infestation is moderate or excessive the carcass is condemned.

For many years it was assumed that the rarity of the pork tapeworm in man and swine in this country was due to the fact that the American people were not in the habit of eating rare or raw pork, a habit which is well established among the people of certain countries of Europe. Unfortunately, in the light of the evidence to be presented in connection with the next and final topic, trichinosis, this assumption does not appear to afford the entire explanation. Federal and other competent meat inspection offer the public the greatest measure of protection against the pork tapeworm. The importance of cooking pork thoroughly will be discussed in connection with trichinosis. Thorough cooking of pork will absolutely preclude the possibility of infestation with a tapeworm that is very dangerous to human health.

Trichinosis

Trichinosis is a disease of human beings, swine and other animals. The parasites which produce this disease are small cylindrical worms, known to zoologists as *Trichinella spiralis* and commonly known as trichinae; these parasites occur in a great variety of carnivorous and omnivorous mammals. So far as human trichinosis in this country is concerned, only swine need be taken into consideration, since practically all the known cases of human trichinosis in the United States that have been definitely traced to their source were shown to have resulted from the consumption of raw or undercooked infested pork or to the consumption of inadequately cooked or cured meat food products containing infested pork muscle tissue. A few cases of trichinosis have been traced in this country to the consumption of jerked bear meat, and in Germany this food was responsible for a serious outbreak of trichinosis several years ago.

Unfortunately, pork that is infested with trichinae does not differ in appearance or in taste from uninfested pork. The trichinae that occur in the flesh of hogs are very small, measuring only about one twenty-fifth of an inch in length and about one eight-hundredth of an inch in width. The individual worms are spirally rolled and enclosed in capsules which are somewhat less than one fiftieth of an inch in diameter and hence, microscopic in size. The capsules do not stand out in contrast to the meat, except in infestations of long standing. Considering the minute size of encapsuled trichinae, it is impossible, of course, under meat inspection procedure, to detect their presence in pork with the naked eye. Microscopic inspection of pork for trichinae is practiced in some European countries. Such inspection, however, is inherently imperfect, many infected carcasses, especially those moderately or lightly infected, being overlooked. Knowledge of the existence of a microscopic inspection of pork would tend to create a false sense of security in the minds of persons who are fond of raw pork, and this would tend to promote rather than discourage the unhygienic custom of eating pork in a raw or semicooked state. In the United States, microscopic inspection for trichinae of pork intended for home consumption has never been undertaken. Consequently, pork that is passed under federal and other meat inspection as being fit for human food may be infested with trichinae, and for this reason pork should always be cooked. If infested pork is eaten raw or insufficiently cooked, seri-

ous consequences are apt to follow and sometimes do.

During the year 1937 three serious outbreaks of trichinosis were reported in the press. Through official correspondence, the Bureau of Animal Industry ascertained the facts in each outbreak from the health officer of the community concerned or from the physician who treated the patients. These three outbreaks illustrate how trichinosis may be contracted and afford information on the seriousness of this disease.

Early in December of last year, a farmer, Mr. X, living in Flathead County, Montana, a Russian by birth, and the father of eighteen children, prepared a lot of smoked sausage which contained venison mixed with pork obtained from hogs slaughtered on his own premises.[1] These sausages were eaten by X and his immediate family. Some of these home-made sausages were distributed by the kindly father to his married sons and daughters, and they in turn, partook of these home-made products and, with characteristic western hospitality, distributed the surplus products to their friends and neighbors. The available evidence indicates that the immediate family of X, and some members of the families of his sons and daughters and those of some of their friends ate these products without cooking or only after slight cooking or warming. As a consequence thirty-eight persons became ill, Mr. X and members of his immediate family being the first ones to show symptoms of illness.

The first symptoms shown by the members of the stricken family were a general tired feeling and headache, these being followed by nausea, vomiting and sharp gastro-intestinal pains. These early symptoms were followed later by pains in the eyes and a marked swelling of the lower eyelids; at the same time marked swellings were noted in the muscles of the lower portion of the abdomen and in the flexor muscles of the limbs. The symptoms mentioned, especially the early symptoms, were, in the opinion of the attending physician, suggestive of food poisoning, and it was suspected that the venison which was one of the constituents of the sausage might have been tainted. As the patients failed to improve, but grew instead increasingly worse and developed fever, the state epidemiologist, who was notified of this outbreak, visited the premises, and obtained samples of water and samples of blood and stools from the infected persons. The samples were submitted to the state health laboratory for bacteriological examination; the results were negative. The youngest member of the family in the meanwhile became severely ill and was placed in a hospital, where the usual laboratory examinations were made, including a microscopic examination of the spinal fluid, a spinal puncture having been resorted to because meningitis was suspected. One microscopic field showed a single trichina larva, and this at once led to a suspicion that the patient, as well as the other members of the family, was suffering from trichinosis. Samples of the pork sausage still available on the farm were sent immediately to the laboratory of the Montana Livestock Sanitary Board, and a telegraphic report from that laboratory to the hospital contained the information that the sausage was heavily infested with trichinae. The hospitalized patient succumbed to the infection about three weeks after eating the infested sausage. In the meanwhile other persons outside of X's immediate family became ill and on the date of the last report 38 persons, as already noted, were ill and suffering from trichinosis.

The symptoms shown by the affected persons were due to the progress in the growth, development and migration of

[1] The account of this outbreak is based on information supplied by the attending physician.

the trichinae in the bodies of their victims. The early gastro-intestinal irritation and pain were the result of the growth and development of the worms in the intestine, and the swellings and pain in the muscles were caused by the penetration into this tissue of the newborn trichinae, which wandered from the intestine in the lymph and blood stream until they reached the muscles. The symptoms which were suggestive of meningitis were due, at least in part, to the penetration of the wandering worms into the central nervous system.

One of X's daughters ate some of the sausage well cooked and escaped infection, while several members of her family who ate the sausage only half-cooked became ill. A neighbor of one of the beneficiaries of X's generosity is said to have stolen a number of sausages and his family of five, including himself, became stricken with trichinosis.

A sample of the sausage that brought about this epidemic was forwarded to the Bureau of Animal Industry and was found in our laboratory to contain approximately 2,800 trichina larvae per ounce. A piece of muscle from one of eleven hogs purchased from X by the Montana Livestock Sanitary Board and later slaughtered was examined in our laboratory and found to contain an average of about 168,000 trichinae per ounce.

This outbreak has been described in detail because it illustrates the point that human beings acquire trichinosis from eating raw or slightly cooked pork, shows the principal symptoms of trichinosis, and that this disease may terminate in death. The data given afford conclusive proof that the suffering of those stricken as well as the untimely death of the youngest member of the family could have been avoided, if the sausage in question had been cooked, as shown by the experience of one of X's daughters, who apparently did not share her family's fondness for semi-raw pork. The case history of the boy who succumbed to trichinosis illustrates that this disease may be confused with other febrile diseases, such as food poisoning and meningitis. Trichinosis is commonly confused with typhoid fever and occasionally with undulant fever.

Another outbreak which occurred late in October of last year involved forty-four persons in one of the New England states. Fortunately all these cases were moderate or mild. The infection was traced to a meal of undercooked pork loin of which all the persons who later became ill partook. The diagnosis in these cases was established on the basis of clinical symptoms.

Still another outbreak occurred late in the summer in Rochester, New York, and came about as follows: A social organization of that city held a picnic, which was attended by about 200 members. The food served was of the customary picnic variety, including pork sausage, which was cooked hurriedly and avidly consumed by the picnickers, following several hours of exercise in the open. The resultant casualties were as follows: Stricken with trichinosis, 85; succumbed to the disease, 1. Aside from the fatal case, only a few individuals developed sufficiently severe symptoms to warrant hospitalization; most of those stricken escaped with rather mild symptoms and were treated in their homes. An article regarding this outbreak, published in the bulletin of the Health Bureau of Rochester, New York, contains the following significant statement: "All this suffering could have been so easily prevented, if only the pork had been thoroughly cooked."

The total number of cases involved in the three outbreaks is 167, with two deaths. In addition to these cases, there occurred during the year a number of more or less isolated cases in various

parts of the country which probably will bring the total number of reported cases of the year up to about 250.

In the absence of an economically practical method of inspection of pork to detect infected carcasses and in the absence of a practical system of rendering fresh pork and ordinary varieties of cured pork safe for consumption before the meat is released for sale, the consumer should protect himself by cooking all pork thoroughly, unless he has definite assurance that a particular processed pork product intended to be eaten without cooking was prepared with this in mind in a meat-packing establishment operating under federal inspection or competent state or local inspection. Whenever any doubt exists as to whether a particular product may be eaten without cooking, it should be cooked thoroughly.

Under federal meat inspection, all products containing pork muscle tissue that are to be sold as cooked products are heated or cooked under the scrutiny of inspectors, according to methods which are known to insure a sufficiently high temperature to destroy in all parts of the meat the vitality of any trichinae that may be present. For all products which are not cooked or heated to a sufficiently high temperature, but which are nevertheless intended to be eaten by the consumer without cooking, various alternative methods of preparation are prescribed, such as prolonged freezing at low temperatures, or curing, smoking and drying in accordance with methods that are known to insure the destruction of life in all trichinae present. As already stated, for fresh pork and ordinary varieties of cured pork, there is no inspection or required treatment for reasons already given.

Some persons, upon discovering that between 1 and 2 per cent. of hogs in this country contain trichinae, and that these parasites are dangerous to human health, conclude that all pork, no matter how prepared, is dangerous. Such a conclusion is unsound and unwarranted. There is no danger whatsoever of acquiring trichinosis or any other parasitic disease from thoroughly cooked pork. Cooking of pork is a health safeguard and is comparable to the pasteurization of milk, the chlorination of drinking water and similar hygienic measures that have been adopted the world over to protect human health. If one concludes that there is something wrong with pork because it must be cooked to make it safe, to be consistent such a person would also have to conclude that there must be something wrong with milk because it is commonly pasteurized. As is well known to hygienists, cooking is the greatest health safeguard; the facts presented in this paper confirm this generalization.

THE SURFACE OF THE NEAREST STAR

By Dr. ROBERT R. McMATH

THE McMATH-HULBERT OBSERVATORY, UNIVERSITY OF MICHIGAN

THE atoms in the surfaces of all the billions of stars accessible with our telescopes may fittingly be compared to minute sending stations, broadcasting each on its appointed multitude of narrow wave-length bands, preserving their allotted "channels" with almost infinite exactitude and endeavoring thus to send us certain important messages relating to the temperature and the constitution of the stars in which they are located. With our telescopes, and to a far greater extent with those optical receiving stations we call spectrographs, we are today reading a few of the messages these distant stars are endeavoring to broadcast to us.

Certain equally important messages relating to the actual spatial behavior and physical movements in stellar surfaces seem, however, permanently beyond our reach. For no telescope, existing, projected or imaginable, can show a star to us as anything but a diskless point of light; an actual stellar diameter of a million miles or more will vanish almost into a mathematical point at stellar distances of trillions or quadrillions of miles.

Thus it becomes very fortunate for our knowledge of the distant stars that we have a star so close at hand that we can see its disk and study the actual motions on its surface. The star referred to is, of course, our own sun, a mere bagatelle of ninety-three millions of miles distant, and, fortunately for the truth of the deductions we may make from it as to the surface behavior of stars in general, a respectable, run-of-the-mill, middle-aged star, neither very hot nor very cool as stars go, and neither a giant nor quite a dwarf among its millions of brother suns. The entirely average position of our sun as to size, luminosity, mass and other characteristics thus facilitates and makes more probable any deductions we may wish to draw from it in application to more distant suns. To repeat, any study of the stars of our universe must start with and be based upon a study of our nearest star—the sun.

About twelve years ago the writer, with two most helpful colleagues—Judge Henry S. Hulbert and the late Francis C. McMath, my father—decided that a fallow and hitherto neglected field lay invitingly open for research through the application of the motion picture to such astronomical phenomena as exhibit rapid motion or change. A small, but most completely equipped telescope was designed and built for the highly exacting technique of the motion picture as applied to astronomical photography, and this installation was located at Lake Angelus, about five miles to the north of Pontiac, Michigan. The instrumental equipment was gradually augmented and improved through several years of gradual evolution and development, too long and too technical to detail here, and in 1931 the plant, under the name of the McMath-Hulbert Observatory, was deeded by its founders to the University of Michigan.

Our initial aims were frankly educational. We envisaged the manifold assistance that carefully planned astronomical films would give to the work of astronomical instruction in schools and colleges. How much more effective it would be, we reasoned, to project for a class a three-minute film, showing, for example, the rotation of the planet Jupiter on its axis and the revolutions of its moons about the planet, than merely to lecture to a class that such things were

happening. Many thousand feet of such educational films were taken by the McMath-Hulbert Observatory of planets and their satellites, the phenomena of sunrise and sunset on the slowly rotating moon, and similar subjects, and a considerable number of educational reels of such types have been shown to scientific societies and distributed to schools and colleges.

It is with a feeling of some regret that we have had to drop most of our efforts to provide purely instructional adjuvants for astronomical teaching—we hope only temporarily—for we are still firmly convinced as to the great value of such astronomical films for the instructor as well as for the student.

The reason for this temporary abandonment is comparatively simple; it has come about merely because a further extension of this motion picture technique to that nearest star we call the sun has opened up such new and astonishingly inviting fields of scientific research that we have been compelled, willy-nilly, to devote every waking moment to a new and fascinating field of most useful scientific work on the sun—the actual depiction of the storms around sun-spots, and the intricacy of the motions of the mighty gaseous prominences that rise for many thousands of miles above the solar surface, and move and change and disintegrate with speeds that range from a few miles per second up to explosive velocities of several hundred miles per second. The many puzzles which are exhibited by these new pictures, some of which remain as yet unsolved, force us to the conclusion that our initial purely educational aim must give ground for the present to a program of pure scientific research.

There are several respects in which the new motion pictures of solar phenomena are unique, and we may be pardoned for assembling certain of their outstanding characteristics at this point.

(1) These pictures are in a very real sense "modern," inasmuch as the first solar films taken with the new McMath-Hulbert tower telescope were made on July 2, 1936, one day after the completion of the tower.

(2) They are definitely unique, because no other installation at present exists which has the instrumentation for similar motion picture records of solar phenomena.

(3) They were the most nearly *continuous* records of solar phenomena ever made, and in this factor, as will be noted below, lies perhaps the largest portion of their value as scientific documents for research purposes. Photographs of the solar surface in white light, and spectroheliograms of solar prominences in the light of calcium or hydrogen have been taken for several decades, but most of these were effectively "stills," to use the terminology of the motion picture studio. Such stills, taken at time intervals of an hour or less, have given valuable data as to the changes occurring in solar features; the continuous character of these new records shows, however, the changes *as they are taking place*, and not only make possible a more detailed study of the mechanisms underlying the phenomena, but also have brought to light a mass of new details, hitherto unsuspected, and unrecorded in the still pictures of the past.

There are in the world to-day seven tower telescopes for studies of the sun; that at Lake Angelus is not only the most recent, but embodies many refinements of design. This instrument may be succinctly described as a telescope which remains fixed in a vertical position, with an arrangement of motor-driven mirrors at the top of the tower, termed a coelostat, to follow the sun as it moves across the sky and to throw its image vertically downward; the Lake Angelus instrument is approximately fifty feet in height. The various mirrors in this optical train are of pyrex, which is [illegible] for solar instruments because of its very low coefficient of [illegible]. These [illegible] coating of [illegible]

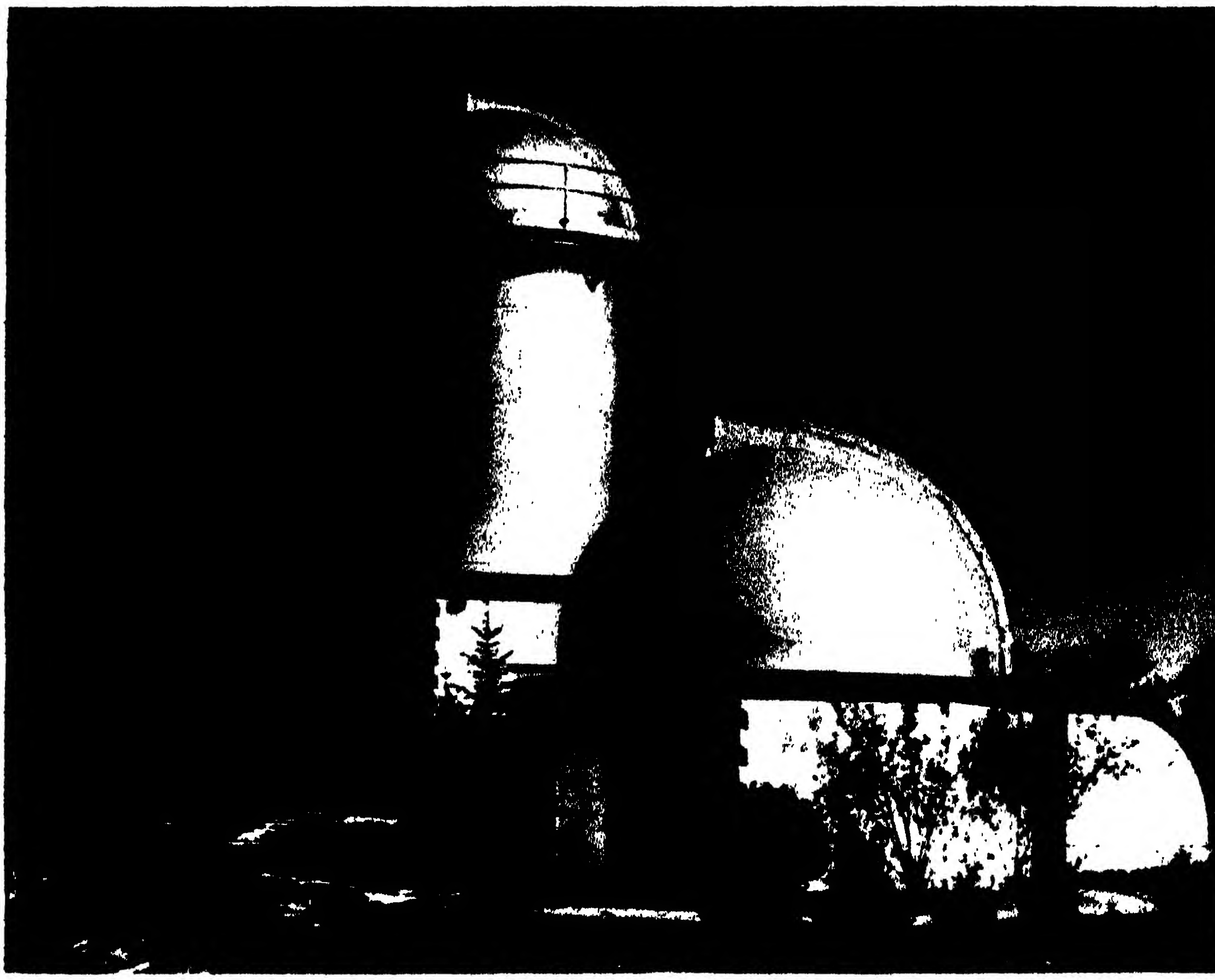
oration in a vacuum; due to this use of mirrors rather than lenses, we have an achromatic telescope that is exceedingly rapid photographically. For this reason, the exposures with the Lake Angelus apparatus may be made very short; exposures on solar prominences in current work range from ten to thirty seconds, where most other installations must count their exposure times in minutes rather than in seconds; such short exposures make for a record that is practically continuous.

At the bottom of the tower the solar image formed by the mirror train falls upon the slit of a spectroheliograph. This rather technical instrument may be briefly described for the layman as a spectrograph which passes the light from the solar image through a narrow slit and then through a lens to a grating or prism which is located in a heavy rotatable steel cage in a well thirty-five deep beneath the tower. The grating disperses and spreads out the light in the form of a spectrum and reflects this spectrum through the same lens back to the upper end. Here a second slit is installed that is the "heart" of the apparatus. With this second slit we pick out some one particular wave-length of some element in the solar spectrum and *throw all the rest of the solar light away.* Solar prominences, for example, are particularly rich in the elements calcium and hydrogen. Thus we may pick out one definite wave-length of calcium and secure a photograph of a narrow strip of the sun where the solar image falls upon the narrow slit, *in calcium light only,* where an ordinary photograph in "white" light would show nothing, because of the overpowering brilliance of the light coming from other chemical elements in the sun. But a photograph of a narrow strip of the sun in calcium light would be useless and almost meaningless; what we need is a calcium or a hydrogen light picture of a considerable area, either of the solar disk itself or of an area at the solar limb where some large prominence is seen in profile. To secure such a picture of an area, the first slit is moved back and forth over the chosen area of the solar image and the second, or "picking-out" slit is given a precisely equal but exactly opposite motion, so as always to receive the calcium wave-length of the spectrum reflected from the grating, and that wave-length only.

The result of this scanning process, performed twice a second, is a calcium or a hydrogen picture of an area. Some other elements may be selected as well, in case we wish to secure an iron picture or a helium picture, and all these pictures in the light of some chosen element would ordinarily be entirely invisible, but are made possible only by this process of sorting out a definite wave-length and discarding all the rest of the light from the sun.

The above brief and schematic description, manifestly, can give but a slight idea of the actual complexity of the apparatus, some conception of which may be derived from the fact that there are about forty small electric motors scattered over the tower mechanisms from the coelostat at the top to the grating cage down in the well, and each of these is controlled by its individual push-button. In these respects the present installation is doubtless the most convenient in existence, as the observer at the spectroheliograph head can perform any adjustment or manipulation without leaving his station, merely by pressing an electric push-button.

The apparent complexity of certain features of the mechanism of this tower telescope is, in some senses, merely a necessary consequence of the exacting technique that has been found indispensable for the taking of satisfactory motion pictures of this and other celestial phenomena. A "run" or "scene" may comprise anything from a few hundred to over a thousand separate pictures on the film; the word "frame" is customarily used for these individual pictures; six or eight hours of continuous work



Photograph by Sidney D. Waldon

THE McMATH-HULBERT OBSERVATORY OF THE UNIVERSITY OF MICHIGAN

will ordinarily go into a run comprising a thousand separate frames.

Manifestly, all the frames of a scene must be as perfectly registered as possible, to avoid flickering and unsteadiness on the screen. Early in the work on the moon and planets that preceded this solar work, it was found that no existing form of telescope drive gave sufficient accuracy. Accordingly, merely as a by-product of the larger program, and after four other methods had been tried and found wanting, a new and improved form of telescope drive was devised, based upon an infinitely flexible and instantly variable control of the input electrical frequency to the telescope drive motor, secured through resistance-ballasted thermionic tubes. This form of telescope drive is known as the McMath-Hulbert electric drive; it brings it to pass that the telescope becomes an automatically *following* instead of a manually *guided* apparatus; it has since been adopted for the drive of the McDonald reflector in Texas, for three telescopes at Lick Observatory, and is under consideration for other projected large telescope mountings. The instruments at Lake Angelus were also the first to employ a similar accurately controlled drive in the declination component, in addition to the ordinary motion given in the right ascension coordinate.

In the astronomical motion picture technique, it must also be possible to arrange for any probable desired duration of the actual exposure, as well as for the duration of the "dark time" between exposures. A gearing train in an underground control room adjacent to the tower makes possible the selection of these times and controls the shutter of the special motion picture camera. A

description, or even a bare tabulation, of all the necessary mechanical details is, however, manifestly impossible in a general article. Only one additional desideratum may be noted. The hundreds of separate frames in a scene would have scant scientific value as records of motion and change if accurate timing arrangements were not provided. Accordingly each individual frame automatically makes a record of its time electrically on a continuously running chronograph in the underground control room.

With an exposure of twenty-seven seconds on a solar prominence and a dark time of three seconds, two frames will be taken per minute; they will be projected on the screen at the customary rate of sixteen per second, or 960 frames per minute. Thus it will be evident that the projected picture will have a "compression factor" of 1:480. Such a compression of the record is not only inevitable, but a very distinct advantage, rather than a detriment.

Suppose, as is not at all unusual, that a bright knot is seen to form 100,000 miles above the solar surface and then to descend at the rate of 40 miles per second, about average as solar prominence velocities run, but still 80 times the speed of a high-power rifle bullet. Its total time of descent to the sun will be forty-two minutes. Instead of having to wait that long in our seats to see the history of this descending knot, the above compression factor of 1:480 reduces it to about 5 seconds, and a scene which is made up of several such knots in motion will occupy the very convenient interval of 20 or 25 seconds and appears practically continuous in its record of motions and changes.

By design, considerable space has here been given to an outline of the technique of the motion picture as adapted to an astronomical end, and the apparatus necessary for the purpose, in order to emphasize, not only the more difficult features of the research on its mechanical side but also the unique character of the resulting record.

During the seasons of 1936 and 1937 over ten thousand feet of standard 35 mm film have been exposed in the new tower telescope on the solar prominences or on features of the solar disk itself. Even though every possible mechanical convenience or electrical adjustment has been provided, and even though this tower telescope has been pronounced to be the most rapid, flexible and convenient in existence, the total amount of labor and attention involved in taking over one thousand separate photographs in the run on a clear day which may extend from 8 A.M. or earlier till 6 P.M. is very considerable. It is a pleasure to make acknowledgment at this point to my two colleagues and to those who have assisted in the somewhat complicated technique of solar prominence photography and measurement—to our research associate, Dr. Edison Pettit, of the Mount Wilson Observatory, and to Harold E. Sawyer, assistant astronomer, and John Brodie, assistant, in the McMath-Hulbert Observatory; others have given assistance for shorter periods. We owe also a special debt of thanks to Dr. Heber D. Curtis, director of the observatories of the University of Michigan, who has, from its very inceptance, given every encouragement to this program of solar research and every assistance within his power.

These films, when projected under proper conditions, show scenes of unexampled grandeur, and radically change our preconceived notions of the surface of a star. Though we knew from the "still" photographs of the past that the sun's surface was marked by constant activity as manifested by those solar storms called sun-spots, by the flocculi and by the prominences, these films for the first time bring to us the actual motions in a continuuous record, which we may repeat as often as we need for our scientific studies. These motion pictures very effectively change our conception of

Drawing by Russell W. Porter

THE 50-FOOT TOWER TELESCOPE OF THE McMATH-HULBERT OBSERVATORY.

a star's surface from something at least relatively static to a picture that is intensely kinetic; we begin to realize that the surface of a star is an unending maelstrom of motions due to titanic forces whose precise nature can not as yet be regarded as completely explained.

Even though we are astronomers, we are very human, and we too derive much the same pleasure as does the layman who

sees these films and is enthusiastic in his praise of them, viewed merely as inspiring spectacles. And yet, strange as it may seem, we who are taking and studying these new records of solar activity take rather amiss the enthusiastic praises we hear from laymen or from scientists in other fields who apparently regard them as merely interesting "movies." We feel quite strongly that the magnificence of these displays is, in many respects, only a very secondary consideration in our evaluation of these pictures as scientific records, from which facts of very definite value are being derived as to the actual nature of the surface of a star.

"Conflagrations," explosions, skyrocket sheaves of light like the grand finale of the 4th of July celebrations of our boyhood, are all admittedly inspiring when we realize the tremendous speeds that are actually involved, the temperature of more than 10,000° Fahrenheit, that our picture embraces an area 150,000 miles high and 200,000 miles wide, and that our earth would be but a small disk on the same scale and quite unimportant in comparison to the mighty flames and streamers of incandescent gas that form these solar storms. Yet to us the motions and laws of motion that we are deriving and the nature of the mysterious forces that seem eternally operative on the surface of a star are much the more important considerations as we view these new films.

This new method of attack on the problems exhibited by the surface of a star is still too youthful to permit of explanations of each and every phenomenon observed. Fresh puzzles too frequently show themselves in each run on a new and active prominence, and if the history of our past work is any criterion, the coming season of 1938 will bring to light as many new features as have those of the two preceding years. The complexity of some of the more active prominence displays frequently baffles description, and we often find that the only way to be sure of all that is taking place is a repeated showing of the film; frequently we will notice some minor peculiarity or puzzle in the tenth or twelfth showing that had previously escaped us and had, of course, never been suspected in the still pictures of the past.

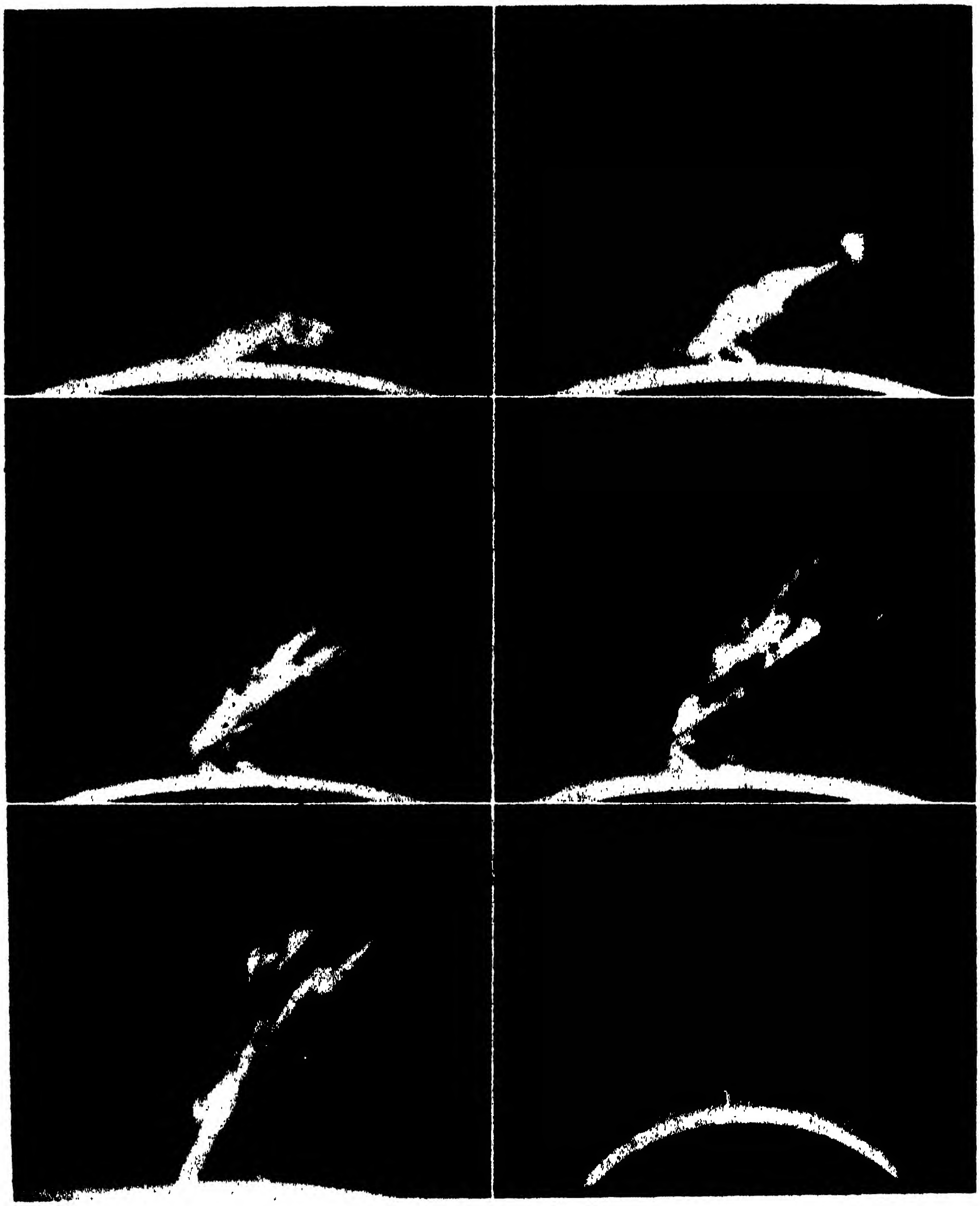
While, as already noted, we are still working on many of the puzzles presented, and are withholding a more precise formulation of hypotheses till more data have been collected, some of the results of the work on the sun with the new tower telescope and our improved motion picture technique may be assembled as follows, either in more general statements or in descriptions of isolated phenomena.

(1) It has become necessary to add three subdivisions to Dr. Pettit's accepted classification scheme for solar prominences, to include three new types of prominence whose existence was not hitherto suspected. These are:

(a) *Surges.* These are very short-lived prominences like spear-heads of flame, that stab upward 1,000 to 10,000 miles or so from the solar chromosphere and as rapidly subside again, with a total life period of only a few minutes. As seen in profile in runs on prominences, the limb of the sun will occasionally exhibit an almost continuous activity of this type. In pictures of the solar disk proper, the sudden short-lived splotches of brilliant light that appear and disappear in areas about sun-spots are believed to be these same surges, seen from above.

(b) *Ejections.* This name has been given to the balls of luminous chromospheric matter thrown out of sun-spot areas like Roman candle displays. They are relatively faint and seem to leave the sun without returning. In one or two cases these balls seem rather more like hollow spheres or perhaps in the form of smoke rings; it is difficult to decide with the material now available.

(c) *Coronal type streamers.* These



GREAT ERUPTIVE PROMINENCE OF SEPTEMBER 17, 1938, PHOTOGRAPHED AT THE McMATH-HULBERT OBSERVATORY.

A—$14^h50^m.69$; B—$14^h55^m.84$; C—$15^h06^m.13$; D—$15^h09^m.11$; E—$15^h14^m.31$; F—$16^h06^m.7$ G.C.T. EXPOSURES A TO E WITH 20-FOOT FOCUS MIRROR, F WITH LENS OF 74 INCHES FOCAL LENGTH. IN F THE PROMINENCE GOES OUT OF THE PICTURE 1,000,000 KM ABOVE THE SUN.

are very puzzling. In such streamers matter appears to form, or more properly to become luminous, at an altitude of 120,000 miles or more above the surface of the sun and then to descend in successive streamers to the solar surface.

These coronal streamers are generally rather faint and have never been detected before.

(2) Several very interesting examples of *violently eruptive* prominences have been recorded. For one of these, taken in September, 1937, though the entire period covered by the scene was only 80 minutes, the upper portions could not be kept within the motion picture frame in spite of three successive changes to shorter focal lengths; the total height was about 620,000 miles, which held the world's record until the recent record of 900,000 miles for a prominence photographed at Mount Wilson. The velocity of this Lake Angelus prominence reached 432 miles per second; as this is considerably greater than the "velocity of escape" under gravitational attraction at this distance from the sun, this is believed to be the first recorded instance where we have observed matter shot out into space beyond the sun's attraction, though such possibilities have long been recognized in theory.

(3) *Arch types.* Several great arches of unusual interest have been recorded. In one of these it was nearly 100,000 miles between the "feet of the rainbow." Though there was no noticeable accretion of material at the top of this arch, luminous knots of gas are observed continuously descending to the sun in *both directions* from the summit of the arch. Why?

(4) *Predominance of matter in descent.* Even if we include the prominences of eruptive type mentioned under (2) above, perhaps 90 per cent. of our prominence scenes record matter in descent only. On a number of great "banyan-tree" prominences, with multiple stalks or trunks connecting the enlarged upper portions to the chromosphere, bright nodules of matter will be observed spiralling downward along the "trunks." We have mentioned above under (1), (c) the growth luminescence in, or actual formation of faint clouds high above the sun, from which the coronal type streamers descend, phenomena which seem to necessitate the postulation of some form of solar chromospheric atmosphere intermixed with the corona.

Much the same class of phenomena are exhibited in lower bright streamers of the beautiful "set-pieces" of a fountain type; the motion of descent is here often clear and rapid; any corresponding ascent of matter on a possible rising arm of the complete trajectory is either very much fainter or entirely absent. Astronomers who see these films for the first time frequently attempt to explain this curious phenomenon by ascribing the invisibility of the ascending side of the streamer to the Doppler effect, arguing that some velocity in the line of sight moves the wave-length under observation "off the slit" for the ascending branch and implying that these films give a partial rather than a true picture of these motions. We are utterly unable to accept this explanation in the vast majority of cases, for we have noted only two cases of sudden brightening of small patches near the chromosphere that may possibly be due to the Doppler effect, that is, to a velocity in the line of sight sufficient to bring a different wave-length and hence a previously unobserved detail into the slit of the instrument. But an elementary consideration of the geometry of these prominence arches would predicate roughly equal velocities in the line of sight for matter at corresponding portions of the hypothetical ascending or the descending branches of the arch. Moreover, although workers in the past have maintained that narrow slits are an inescapable necessity in spectroheliographic work, we have, as a result of numerous experiments with wider slits, taken beautifully clear and sharp spectroheliograms in the H alpha line of hydrogen with *both* slits 0.5 mm (about

one fiftieth of an inch) in width. This width would necessitate a difference in radial velocity of about ± 110 kms per second (68 miles per second) to move a portion of our picture off the slit and thus render some parts invisible. While higher velocities are occasionally observed in eruptive prominences, such velocities have only rarely been found in these arch trajectories.

The phenomenon remains a puzzle. It is apparent that what goes down very probably came up, but why should the upward journey be predominantly invisible? Is it that the gases on their upward path are in some different temperature or ionization state, changing back to another and photographically recordable state soon after passing the crest of their trajectory? Data are being collected that may eventually give an answer to this pressing and difficult question.

(5) Previous work had detected *no motions* within the *dark* hydrogen flocculi. We have been fortunate enough to "catch" and to photograph for a total elapsed time of 5½ days an enormous hydrogen flocculus whose total length must have been of the order of 700,000 miles, extending over a considerable portion of the solar disk. Its internal motions and its final disintegration were clearly recorded. So far as is known, this is the first case where the life-history of one of these dark hydrogen flocculi has been followed from its first appearance to the end.

(6) Abundant confirmation has been secured in the study of motions in prominence streamers in support of the curious *laws of prominence motion* discovered earlier by Dr. Pettit. The velocity of a prominence or prominence formation is uniform, increasing suddenly at intervals. When there is a change in velocity the new velocity is generally a simple multiple of the previous velocity. That is, a knot that has been moving along a streamer, at a uniform speed of, say, 21 miles per second will suddenly (sometimes in less than a minute) be accelerated to a uniform speed of 42 miles per second, without any apparent transition through intermediate velocities. This puzzling phenomenon has been studied and extended to include nearly all prominence types at Lake Angelus. Like some others found in the Lake Angelus work mentioned above, it shows that we have many still unknown factors with which to deal before we can secure an explanation of all the laws that govern the motion of gaseous matter near the surface of a star.

Such, then, are some of the results, as well as some of the problems, that are growing out of the application of this new technique to the study of a star's surface behavior; the work is being continued as fast as time and money will permit. The very richness of the material being secured has its embarrassing features; it will easily be seen that the detailed measurement of the motions even in one tenth of the frames of a prominence picture that includes over a thousand separate pictures involves a great deal of time and not a little calculation. The number of the prominences, as well as the number and the activity of the flocculi and other disk features, shows an intimate connection with the curve of the number of sun-spots that reaches a maximum roughly every eleven and a third years. We have recently been passing through a period of maximum sun-spot activity, but we do not yet know what detail changes in prominence activity will be observed on our films at a sun-spot minimum. We are inclined to predict that while we shall then have fewer prominences on which to work, they still will be of equal value in formulating theories of the surface layers of a star. Certainly only a beginning of our program of research will have been made until we have worked completely through at least one sun-spot cycle.

THE HIGHEST ERUPTIVE PROMINENCES

By Dr. EDISON PETTIT

CARNEGIE INSTITUTION OF WASHINGTON, MOUNT WILSON OBSERVATORY

PROMINENCES on the sun may be classified into active, eruptive, spot-type, tornado and quiescent. Seen on the disk of the sun quiescent prominences look like ragged ribbons, which indeed they are, standing on edge. Representative dimensions are 10,000 km thick, 200,000 km long and 50,000 km high.

The outward form of these quiescent prominences changes slowly, but usually the change from hour to hour is unmistakable. The internal structure, on the other hand, is in constant turmoil. Velocities of 10 to 20 km/sec are common among the knots and streamers of which they are composed.

Just how these prominences make their appearance is still something of a mystery. I think the usual assumption is that they rise directly out of the chromosphere, for they are commonly attached to it by connecting streamers or strips; but unfortunately for this idea, what motion we have been able to detect by cinematography at the McMath-Hulbert Observatory, is downward to the chromosphere. It must be admitted that at present we know nothing of the formation of these objects. Their destruction, on the other hand, we have witnessed on a number of occasions.

Usually the destruction of one of these prominences proceeds as follows. A center of attraction or a sun-spot forms nearby and begins to pull streamers from the prominence. A center of attraction is not marked in any way on the chromosphere; and we suppose it to be a local electrical charge, since it may occur anywhere on the sun's surface. Ordinarily the activity increases, and broad ribbons of material are pulled off. These ribbons arch upward, the whole prominence rises, swings through a wide arc and is sucked into the chromosphere.

As this attraction of the center or spot increases, the prominence rises higher, three or four hundred thousand kilometers, before being pulled back into the chromosphere. We observed one such case at Lake Angelus on July 24, 1936 (Plate 1). When the intensity of the field of attraction reaches this stage long, slightly curved streamers, not associated with the prominence, are sometimes seen entering the center of attraction or spot from outside space. These we have called *coronal* prominences and they were discovered by the motion-picture method at Lake Angelus.

When the force from the center of attraction or sunspot reaches a certain critical value the prominence rises and leaves the sun entirely. These prominences we call eruptive. Thus it is seen that quiescent prominences become associated with the eruptive, through their conversion into active or sun-spot prominences. So far I have never seen a tornado associated with an eruptive prominence.

The earliest published account of an eruptive prominence, which included measurements of height, was by Trouvelot based on observations made at the Meudon Observatory (France) on August 16, 1885, by the wide-slit spectroscope method. This prominence rose from an initial height of 172,000 km to 416,000 km in two hours. Another, observed by Fenyi on September 20, 1893, at the Haynald Observatory (Hungary) with similar equipment, reached 501,000 km. These observations were made either by an eyepiece micrometer or, when the prominence occurred far from the north

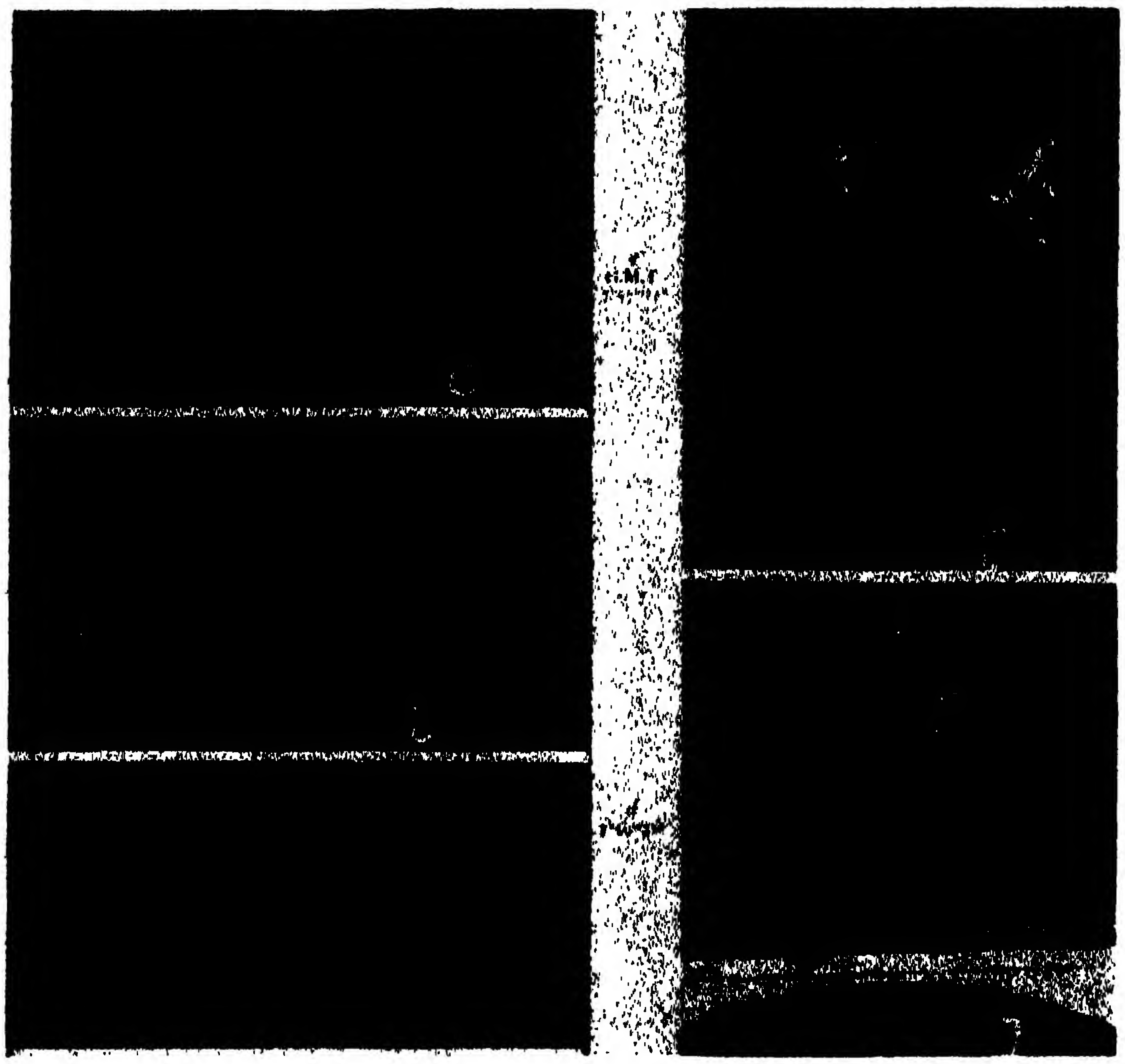


PLATE I. Great eruptive prominence of May 29, 1919, photographed at the Yerkes Observatory. A, $7^h\ 41^m$; B, $8^h\ 57^m$; C, $11^h\ 33^m$; D, $13^h\ 20^m$; E, $13^h\ 57^m$ C.S.T. A sunspot is located near A.

or south point, by stopping the driving clock of the telescope and observing the time interval between the disappearance of the chromosphere and prominence from the field. Fenyi became expert in this latter method.

The first photographic work was done with the spectroheliograph by Deslandres at the Paris Observatory on May 31, 1894. This prominence rose 458,000 km, and one photographed by Hale and Ellerman at the Kenwood Observatory (Chicago) rose 450,000 km, on March 25, 1895. These photographic records stood till Evershed at Kodaikanal (India) photographed one on May 26 1916, that rose 643,000 km from an initial height of 102,000 km in one hour.

Up to this time, 21 eruptions had been observed, mostly by the visual method. One would suppose that something of the characteristics of the motion would have been found, yet the outcome was disappointing. Usually each prominence was observed by an individual, and the eruption had been completed before he realized the importance of a large number of observations. Fenyi, who alone observed many, was convinced that they moved like free projectiles under gravity, in spite of the fact that his observations would not substantiate this idea. Pringsheim in "Physik Der Sonne" thought the observations showed that eruptive prominences rise with erratic motion. Yet, in retrospect we can see that these observations really show both laws of motion found from more precise observations later.

The first real fact of prominence motion was pointed out by Evershed after the eruption of May 26, 1916, when he showed that the velocity increased with the height, although observations were insufficient for critical examination of the velocities.

The eclipse of May 29, 1919, is notable in the annals of science for providing the

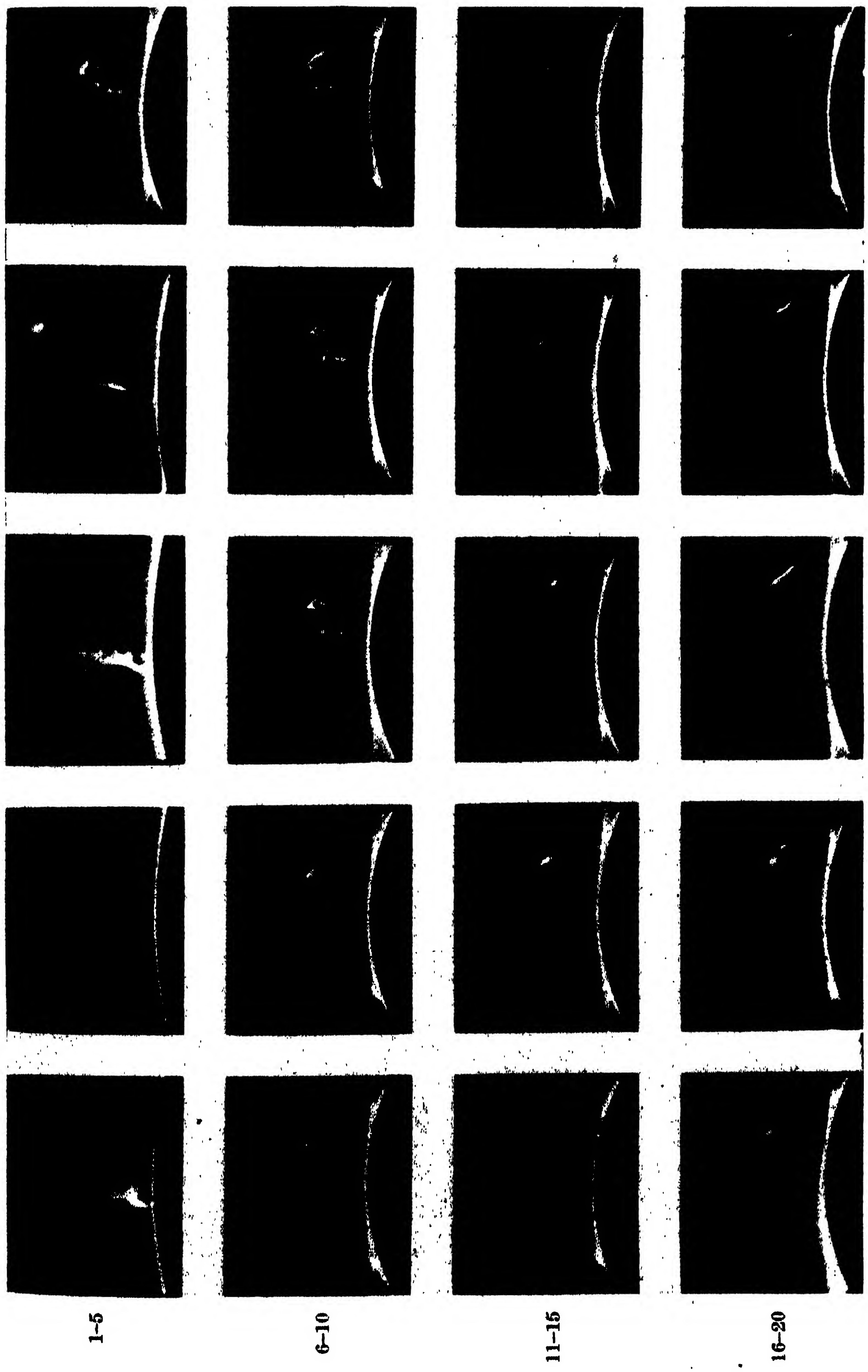


PLATE II. Quasi-eruption of July 24, 1936, taken at the McMath-Hulbert Observatory. Exposures 1–4 with 40-foot focus at 1^h intervals. Remaining exposures, 5–20 with 18-foot focus at 6^m intervals.

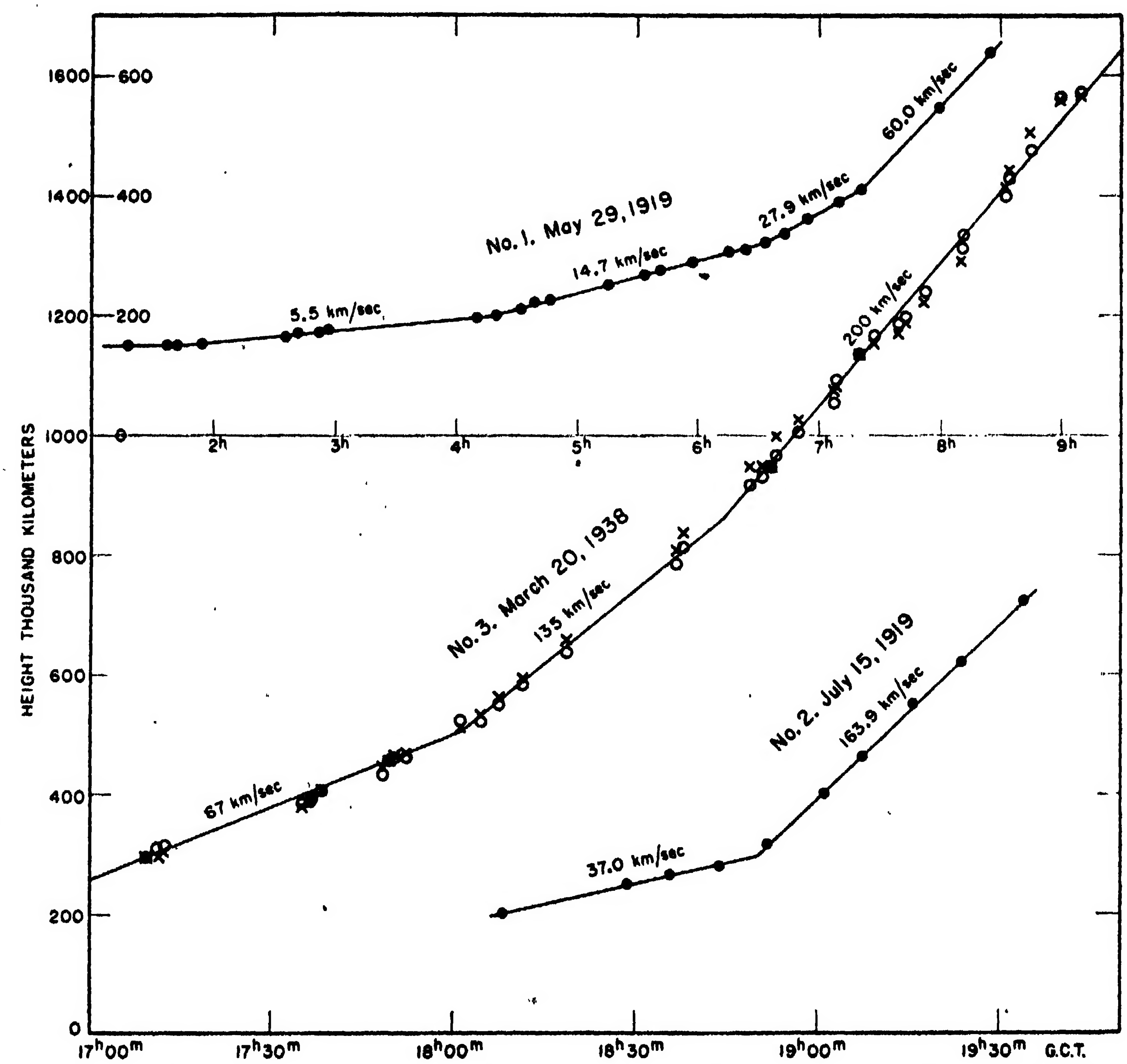


FIG. 1. TIME-HEIGHT DIAGRAMS OF ERUPTIVE PROMINENCES; (1) MAY 29, 1919, (2) JULY 15, 1919, AND (3) MARCH 20, 1938. NOTE THAT THE STRAIGHT LINES INDICATE CONSTANT VELOCITIES WHICH INCREASE SUDDENLY AT INTERVALS.

first positive observational evidence of the validity of the theory of relativity. When the eclipse occurred one of the largest prominences ever seen appeared on the east limb of the sun. The Smithsonian party, located in the Andes Mountains, near La Paz, Bolivia, reported that patches of snow lying on the ground were colored blood red by the light of this extraordinary prominence during totality.

I was at the Yerkes Observatory at this time working on the problem of motions of prominences. This prominence had been photographed with the Rumford spectroheliograph several times since its first appearance on March 22. On May 28 it appeared as a very large object, full of streamers. In those days the observatory operated its own power plant, and Professor Frost arranged that it should start early next day and the rising floor should be left at its highest point in the 40-inch dome, so we could start changing to the spectroheliograph with the least loss of time.

May 29 was a remarkably clear, warm day, favorable to solar observations. One of the difficulties we encountered was from gossamer from the cottonwood

trees, which filled the air at that time of year and had to be brushed from the spectroheliograph slit continually.[1] The prominence rose slowly at first, but continued to rise through the entire morning, and for seven hours I followed it till it faded from view.

This prominence (Plate II) rose from an initial height of 200,000 km to 760,000 km, exceeding a solar radius and was the record height for that time. Plate I shows five exposures. The first, taken near eclipse time, shows the prominence pouring into a small sun-spot located at A. Note the streamers which continue to return to the chromosphere throughout the eruption. This phenomenon is common to eruptive prominences.

With this prominence it was possible to determine the center of gravity of the floating cloud with some accuracy, as well as the maximum and minimum heights. On plotting the heights of the prominence against the times of observation (No. 1, Fig. 1), much to my astonishment, it appeared that the observations were represented by four straight lines and that the prominence rose with uniform velocity, increased at intervals, as if by an impulse of very short duration.

Another prominence was observed with the same instrument on the following July 15, resulting in plot No. 2. Further confirmatory evidence was found in a prominence observed through clouds on September 1, 1919, but the data were too scattered to be definitive. It was now apparent that this principle of uniform motion, increasing suddenly at intervals, was a general one and a study of all observations made on eruptive prominences up to that time led me to think this was really a law of motion of eruptive prominences.

It was also noted that each velocity in the prominence of May 29, 1919, was a small whole multiple of the preceding velocity, but the two velocities in the prominence of July 15, which I regarded as being quite accurate, did not follow this principle; in fact, the ratio was nearly 4.5, so this idea had to be given up.

On October 8, 1920, Lee at the Yerkes Observatory, photographed a prominence which rose from 110,000 km to 831,000 km in 5½ hours, which held the record for prominence heights until November 19, 1928, when Royds at Kodaikanal photographed one which rose from 364,000 to 928,700 km in $1^h\ 18^m$. These also verified the first law.

With the advent of our greater knowledge of atomic physics and radiation several theories based on light pressure were proposed to explain the motions of eruptive prominences. All these theories, however, required continuously accelerated motion and thus did not agree with the observations. I therefore returned to the 40-inch telescope in 1930 to secure additional data of a more detailed kind. On August 6, 1931, an eruptive prominence was secured that rose from 49,000 to 620,000 km in four hours. Exposures were made with an average interval of 4.8 minutes, which gave a very definitive velocity determination. Measurements made by three observers independently, and by myself, showed that the first law of motion was unquestionably verified in detail and that the changes in velocity occupied a time interval of the order less than five to ten minutes.

Obviously, the proper way to study such phenomena as eruptive prominences is by cinematic photography. About this time the McMath-Hulbert Observatory at Lake Angelus, Michigan, undertook to solve the problem of its application and secured successful films of the moon,

[1] This fine thread-like and transparent material is not affected by the intense radiation in the solar image formed by the 40-inch objective which will set a stick of wood afire. I once set the spectroheliograph on the sun when a spider had spun his web over the slit frame. When the solar image moved upon the slit the spider went up in smoke, but the web was unaffected.

PLATE III. Eruptive prominence of March 20, 1938, taken at the Mount Wilson Observatory, which reached the record height of 1.11 solar diameters. (A) $9^h\ 12^m$, prominence near N pole of sun, streamer pouring into center of attraction K. (B) $9^h\ 35^m$, (C) $10^h\ 00^m$, and (D) $10^h\ 18^m$ also show streamer. In (D) prominence is already a half solar diameter high; (E) $11^h\ 03^m$ it is 0.8 and in (F) $11^h\ 31^m$ it is 1.1 solar diameters high.

planets and Jupiter's satellites with a 10½-inch reflector. After experiments with a spectrohelioscope attached to the telescope and adapted to motion picture photography, it was decided to build the present tower telescope, designed for taking motion pictures of solar phenomena, and prominences in particular. In 1936 a quasi eruption, a sort of *missing link* between the true eruptions and active prominences, was observed on July 24. Plate II shows 20 stages of this object.

This prominence nearly got away from the sun, but the center of attraction finally brought it back.

On September 17, 1937, an eruptive prominence was secured by Sawyer and Brodie at Lake Angelus, which was followed till it left the frame of the motion picture camera at 1,000,000 km above the sun. This also had the highest velocity, 728 km/sec, ever observed in a prominence. Even at 1,000,000 km it was still sending streamers back to the sun.

The reader will probably say that this record might stand for some time; but matters move rapidly in science. Plate III shows the eruptive prominence observed by J. O. Hickox at Mount Wilson on March 20, 1938, which reached the unprecedented height of 1,550,000 km, or 1.11 solar diameters above the sun. This prominence was almost at the north pole of the sun; that of Deslandres in 1894 was near the south pole. This puts prominence material definitely in the region of the outer corona.

Now it will be interesting to look at some of the best-determined velocities for a moment. Table I shows five prominences for which the velocities could be called definite.

TABLE I

THE RATIOS F OF SUCCESSIVE VELOCITIES V_0 OBSERVED IN ERUPTIVE PROMINENCES

Date	V_0 (km/sec)	F
May 29, 1919..	5.5, 14.7, 27.9, 60.0	3, 2, 2
June 18, 1929..	3 , 19 , 37	6, 2
Nov. 14, 1934..	13.5, 40	3
Sept. 22, 1935..	2.2, 32.5, 130	15, 4

Note that each velocity V_0 is nearly a whole multiple F of the preceding velocity. A survey of all the data to 1935, a period of 50 years, showed that the great bulk really followed the principle that after increase in velocity the new velocity is a small whole multiple of the preceding velocity. This was called the second law of prominence motion. For instance, Lee's prominence of October 21, 1914, gave 7, 22 and 43 km/sec; and Fenyi's of November 16, 1892, gave 4.4, 6.6, 28.3, 57.2 and 115.0 km/sec.

However, there is a group of prominences for which the observations are among the most definite, which obey the second law, save for the last velocity. These are collected in Table II.

TABLE II

Date	V_0 (km/sec)	F
Aug. 6, 1931....	5, $\underline{19}$, 74, 126	4, 4, $\underline{7}$
Sept. 17, 1937....	28, 58, $\underline{186}$, 540, 728	2, 3, 3, $\underline{4}$
Mar. 20, 1938....	$\underline{67}$, 135, 200	2, $\underline{3}$

Here it will be seen that the last velocity reverts to a whole multiple of the one preceding the changed velocity (underlined in the table). The corresponding multiples F are underlined in the table.

Now we can explain some apparent exceptions to the second law among prominences previously observed, including that of July 15, 1919, of which we have already spoken. The observations of these prominences began when the eruption was already under way and the prominence already 200,000 km or more above the sun. We may expect, therefore, that there may have been a change of velocity before the observations began, and the first observed velocity must be a small whole multiple of it. This we introduce in parentheses in Table III.

TABLE III

Date	V_0 (km/sec)	F
July 15, 1919	(18.2), 37.0, 163.9	(2), (9)
June 23, 1924	(14.5), 43 , 73	(3), (5)
Nov. 19, 1928	(40) , 81 , 200	(2), (5)

These hypothetical velocities, then, bring the residue of our well-observed prominences into line with the second law, as modified in Table II.

The reader will now wish to know what makes these eruptive prominences move

in this odd way, for uniform motion over great distances in a gravitational field is hard to understand. Matters are even more complicated for the streamers and knots pulled off from prominences by centers of attraction and sun-spots obey the laws of motion of eruptive prominences, but move in the reverse direction along curved lines. Moreover, eruptions do not always move in a vertical direction, but sometimes at angles of 40° or 50° to a solar radius. The prominence of March 20, 1938, moved at an inclination of 25° to the radius.

Does this material, which is essentially chromospheric in nature, come back? Maybe the coronal prominences are the answer, but that is a guess. No, light pressure has not satisfied the observations; probably we do not know how to apply it to the problem. If we make the most rational assumption, that the energy absorbed in the spectrum (so-called "resonance absorption") is all that is converted into pressure, there is not nearly enough for hydrogen, which is over 97 per cent. of the mass, since we suppose that the proportion of excited atoms is only 10^{-11} of the whole. We must speculate that the Lyman alpha line is 10^{-8} times as bright as the photosphere over the same spectral range, one angstrom, to get the necessary energy.

Some color is lent to this idea by radio fade-outs; they occur only on the daylight side of the earth, hence the ionizing agent is high-frequency radiation and, since we can not photograph it, the wave-lengths must be shorter than the atmospheric transmission limit λ 2897. We really ought to get a rocket outside the atmosphere to photograph the solar spectrum. It is perfectly feasible and the problem deserves a concerted effort for its accomplishment by a laboratory dedicated to this study. We may have to give the rocket a boost with a piece of naval ordnance to conserve the great energy loss now sustained by it in getting under way, and this will raise problems of designing optical equipment which will stand the enormous acceleration involved, but these are also details which are perfectly solvable.

THE FLOTATION OF MOUNTAINS

A THEORY OF OROGENESIS

By Professor ANDREW C. LAWSON
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PRIOR to the middle of the nineteenth century a great trigonometrical survey was in progress in India which included the Himalaya Mountains. In the course of the survey it was observed that differences of latitude determined by triangulation did not check with the differences measured astronomically, for the same pairs of stations. The discrepancy was most marked in the vicinity of the south flank of the great Himalayan range; and was finally interpreted as due to deflection of the plumb line by the gravitative attraction of the mass of the mountains. The amount of discrepancy between two stations on the same meridian and about 5°23′ apart in latitude was 5.″236. Archdeacon Pratt, an eminent mathematician of the day, undertook to calculate what should be the deflection. The volume of the Himalaya above sea level was estimated from surveys of the relief, and the mean density, based on various determinations of their constituent rocks, was assumed to be 2.75. The result of Pratt's studies was that the differences between the geodetic and the astronomical determinations of latitude should be much larger than they were actually found to be. For the two stations above referred to, where the difference was 5.″236, he showed that the discrepancy should be 15.″885, more than three times as much.[1] He explained this by assuming that the ellipticity of the Indian arc of the earth's profile was abnormally large by reason of the uplift of the mountains. This condition, if real, would have increased the difference of latitude obtained by geodetic measurements, and so harmonized it with that found by astronomical observations.

The problem was taken up immediately by G. B. Airy, the astronomer royal, and was discussed by him in a paper presented to the Royal Society[2] less than a month after the presentation of Pratt's paper. Airy contended that the deflection of the plumb line in the region immediately south of the Himalaya was due to a defect of mass in the mountain range. This defect, he argued, must be due to a relatively low density in the region below the range. The mass of the mountain above sea level having a mean density of 2.75 exercises a positive attraction on the plumb bob; but this is more than offset by the lower density of the roots of the mountain, as compared with the normal density at similar depth, where there are no mountains, as, for example, under the plains of India to the south of the Himalaya. This relatively light rock of the mountain roots was, according to Airy, nothing less than the same rock which appears in the mass of the mountain above sea level. When the mountains were formed by the culmination of growing compressive stress in the earth's crust, there was a downward as well as an upward protuberance of the crushed and folded belt. As the mountains rose the downward protuberance of light superficial rock was pushed down into the heavy rock of the deeper part of the crust, and by the principle of flotation supported the range. Pratt had considered the Himalaya as a range seated upon the earth's crust, and had referred

[1] Phil. Trans. Roy. Soc., 145: 53–100.

[2] Phil. Trans. Roy. Soc., 145: 101–104.

the deflection of the plumb line to the gravitative effect of the mass above sea level only. Airy was the first to clearly formulate the view that mountains have depth as well as height and that the latter exists by reason of flotation of light rock in heavy. His explanation of the deflection of the plumb line apears, however, to have been anticipated a few years by the Frenchman Petit,[3] who in 1849 wrote on the probability of a defect of mass beneath the Pyrenees; although he recognized that the deflection of the plumb line might equally well be explained by an excess of mass in the earth to the north of Toulouse. Airy's paper cleared up the difficulties of the Trigonometrical Survey of India; for he showed that the discrepancies in the difference of latitude between pairs of stations are due entirely to error in the astronomical method, as affected by the deflection of the plumb line. The geodetic method is unaffected by this deflection, and gives accurate figures for relative geographic position.

The notion of universal crustal balance and the support of mountain ranges by their downward protrusion into heavier rock, so clearly set forth by Airy, appears to have had little or no influence on geological thought for over three decades. In 1889, however, the idea was revived by Dutton[4] in a brief paper presented to the Philosophical Society of Washington, in which, curiously enough, Airy's interpretation of great ranges as floating masses was not mentioned. Dutton recognized that the larger features of the relief of the earth's surface were due to balance of rock of lower density in the elevations by rock of higher density in the depressions; and he called this principle of balance isostasy. According to him the shift of load by erosion causes a depression of the area of deposition and a rise of the area of denudation; and the vertical movements of the crust so induced are accommodated by a lateral viscous flow of the underlying rock. Since the publication of Dutton's paper nearly fifty years ago isostasy has been generally accepted as an important principle of geology. But like many other important principles it has been slow of application. Most geologists are more concerned with the details of their own particular field of work than with the general principles of their science. Important contributions to our knowledge of the subject have, however, been made by Hayford and Bowie, of the Coast and Geodetic survey, by Gilbert, of the U. S. Geological Survey, by Barrell, of Yale University, and by the Trigonometrical Survey of India.

One phase of the geodetic work carried on for many years in various countries of Europe, India, Canada and the United States has to do with the measurement of the force of gravity at many points on the surface. If mountains were supported by the rigidity of the earth and were sessile on a crustal layer of uniform density, their mass would in every case greatly affect the values obtained for the force of gravity at points along the range. The values after correction for altitude, would be quite different from those obtained on low-lying plains, above the same crustal layer. But the actual values obtained, whether on mountains, plateaux or plains, are remarkably the same, except for minor anomalies, which are chiefly due to failure to correct for the geological factor peculiar to the station. In arriving at the figures for the force of gravity at any point on the surface, the values obtained from the pendulum observations are subject to various corrections, such as for latitude, altitude, topography. But there is always another correction that should be made and rarely is, that is for the local density of

[3] *Compt. Rend. Acad. Sci.*, 29: 729–734. 1849.
[4] *Bull. Phil. Soc. Wash.*, 11: 51–64. 1889.

the rocks in the immediate vicinity of the station. Geodesists usually have no knowledge of this factor, and so the correction is rarely made. This accounts in part for the small anomalies or departures from the theoretical or calculated value for the force of gravity. Notwithstanding this, the anomalies are so uniformly small that the conclusion is justified that mountains are not merely masses above sea level sessile on a heavy layer of the crust, but that equally light rock, by far the larger part of the mountain mass, extends down into that layer; so that both upward and downward protrusions are supported by flotation in it. In other words, the geodetic results tend strongly to establish the validity of the principle of isostasy.

There are certain regions where the uniformly small anomalies are of peculiar significance for the validation of the principle of isostasy. These are regions of low relief, or peneplains, where geologists are quite certain lofty mountains once stood. If these mountains in the heyday of their existence had been supported by the rigidity of the crust, either they must have presented gravity anomalies of enormous amount, and so been at variance with the general gravitative balance of the crust, or if they then presented no large anomalies they should do so now owing to the removal of so large a mass. Large anomalies do not occur in such regions to-day, and it is highly probable that they never did. We are thus forced to accept the validity of isostasy.

Perhaps the most striking and convincing instance of the effect of shift of load upon the earth's crust is that produced by the imposition of the ice-sheet on the northern part of this continent in glacial times and its subsequent removal. At the time of this astonishingly recent event in the history of our planet a load was transferred from the ocean to the continental surface in the form of a vast ice-cap several thousand feet thick. The effect of the imposed load was to depress the surface of the land, and when the ice vanished there was a corresponding recovery from the depression. As the ice-cap slowly waned in response to the advent of a warmer climate, its southern front, receding to the north, impounded the drainage which tended to flow in that direction, and a system of vast lakes was thus created having a wall of ice for their northern shore. The other shores were like those of normal lakes of our day. Along these shores distinctive shore features were built, such as cliffs, beaches, bars, spits and deltas, which of course were at the time of their formation horizontal. With the vanishing of the ice and the consequent draining of the lakes, these horizontal shore lines were tilted to the north; and are all to-day far above sea level, notwithstanding the fact that the surface of the ocean must have been raised by the return of the ice-cap to it as water. The inclination of these shore lines is from six inches to a foot to the mile, and they remain horizontal in directions normal to that of the tilt. They are perfectly plain features, many of which have been surveyed and leveled. The tilt is ascribed by geologists without question to the recovery from depression of the continental surface on removal of the load of ice. Here then is an unequivocal case of disturbance of balance of the earth's crust by shift of load, adjusted, both as to depression and recovery, by plastic deformation of the rock in depth.

To the layman, who may be skeptical of the plastic deformation of the firm rocks of the earth's structure, it may be well to say that the effect of flowage in rocks is a phenomenon familiar to geologists. Many rocks, both igneous and sedimentary, are now exposed at the surface by deep denudation, which have been so attenuated by flowage that their

originally equidimensional mineral constituents have been drawn out into thin lenses or spindles.

The most common shift of load exemplified in geological processes is that effected by erosion. The rivers flowing to the sea are burdened with detritus, either carried in suspension or rolled along the bottom, derived from the waste of continental surfaces. This detritus is deposited at the margin of the continents in the form of deltas and other embankments. In geological time the amount of load thus shifted becomes very large. The delta of the Mississippi, built up since Cretaceous time, is 1,000 miles in extent from east to west, is 600 miles across, and has a maximum thickness of about 6 miles. It contains about 1,500,000 cubic miles of water-laden sediment, or about 1,000,000 cubic miles of dry rock derived from a portion of the North American Continent. The shoreward half of this delta is composed of shallow water deposits from top to bottom. In order to accommodate these deposits the original bottom upon which they rest must have been subsiding during their accumulation. This subsidence is reasonably ascribed to the effect of the load imposed, the latter being accommodated by a counter flow of rock in depth from the area of the delta to the continental area being relieved of load by erosion. This counter flow of mass between loaded and unloaded regions is the essence of the idea of isostasy; since that is the only mechanism whereby balance of the adjoining sectors of the earth could be maintained. Equal masses per unit of area are exchanged, one at the surface and one in depth; but the volumes of those masses may be very different. The density of the dry rock removed by erosion from the hydrographic basin of the Mississippi is about 2.67; that of the rock which flows out in depth from below the delta to compensate the added load is probably about 3.3. Every foot of thickness of material, having a density of 2.67, added to the delta will be compensated by the outflow in depth of a layer of equal weight per unit of area but having a density of 3.3 and thickness of .8 foot. It results from this difference of volume between the mass added to and the mass withdrawn from the area of the delta, that the subsidence of the floor on which it rests is slower than the rise of its surface, so that ultimately the upward growth of the delta will come to an end slightly above sea level. But if the deltaic embankment extend out into deep water, as is generally true of large deltas, the subsidence will there accommodate the deposition of many thousands of feet of sediments. According to the principle of isostasy the load thus imposed on the sea floor is compensated by the withdrawal of an equal mass per unit of area, but of smaller volume, and the distribution of this, by flow in depth, to the continental area, which has been relieved of a corresponding load by erosion, thus maintaining gravitative balance.

Another example of shift of load, which is frequently encountered by geologists, is due to the operation of compressive stress in the earth's crust in excess of the strength of the rocks. Where the rocks are massive and strong they yield to this stress by rupture, and the break commonly takes place on a plane inclined to the horizon, often at low angles. On such a plane a large part of the upper crust may be shoved under the adjoining part and so produce the reverse effect of an apparent overthrust. In this way the upper crust may be locally thickened, and the thickening creates an increase of load in the belt affected. Such thrusting is well known along the front of the Rocky Mountains, the west side of the Appalachians, the north of Scotland, the Alps, the Himalayas and other mountains. If the movement be small the additional

load may be supported by the rigidity of the crust, but if it be large, as in the cases just referred to, the disturbance of balance will be compensated by the depression of the belt into the heavy rock of the deeper crust, and the uplift of the surface caused by the thrust will be only a fraction of that depression. The disturbed and thickened belt will virtually float in the heavy deeper rock. If, however, the deeper, heavier portion of the crust be similarly thickened by thrusting, the column so affected will be overloaded, and the only way that balance can be restored is for the excess mass to sink into and merge with the general mass of heavy rock, without upward flotation. The first uplift of the surface, if it endure long enough, may be eroded away and, when the thickened sima flattens out, the eroded surface on subsidence may become that of a structural valley.

With these preliminary remarks regarding shifts of load on or in the earth's crust, and the way in which the balance thereby disturbed is restored and maintained, under the principle of isostasy, we may now turn to the consideration of mountains.

There are many great mountain ranges in the relief of the earth's surface, the general structure of which is fairly well known to geologists. All these appear to have originated by the operation of compressive stresses in the earth's crust in regions of excessive sedimentation. In both the Rocky Mountains and in the Appalachians, for example, the thickness of sedimentary strata is far greater than in the great plains which extend between these two ranges. Not only is this so, but even more remarkable is the fact that almost the entire volume of sedimentary strata involved in the mountain-making movement, ranging up to about eight miles in thickness, is composed for the most part of beds deposited in shallow water. This means, of course, that the bottom of the basin in which the strata were deposited subsided in proportion, roughly, to the accumulation. We must, therefore, picture to ourselves as the condition which prevailed immediately before the onset of the mountain-making movement, a vast trough in the earth's surface occupied by sediments to a maximum thickness of about eight miles in the middle of the trough, and thinning out both ways to as little as perhaps one per cent. of the maximum. Such a trough or locus of excessive sedimentation is often referred to as a geosyncline. But the only places on the face of the earth where such great thickness of sediments could accumulate are the deltas of the large rivers, where, as has already been observed, very thick deposits become possible by the extension of the deltaic embankment out into deep water, and the subsidence of the sea floor under the depositional load. If this be so, then in the history of the earth great deltaic embankments have been the precursors of folded mountain ranges. And the probable reason for this is that a load of about eight miles of sedimentary strata, spread out over a large area, marks a limit beyond which the surface can not be depressed without collapse under the horizontal stress prevailing in the crust. Thus, if a syncline be regarded as the result of compressive stress, the trough in which deltaic deposits accumulate does not really become a geosyncline until its collapse and the inauguration of the mountain-making movement. The formation of the trough and its filling with incompetent strata are but the preparation for the yielding to compression which makes the syncline. That yielding is the beginning of the deformation which converts the sediment-laden trough into a lofty mountain range. But the compression, and the mashing together of the strata in steeper and steeper folds, signifies a concentration of mass in the

locus of the trough. The load on the crust along its length is increased. The lateral compression induces the development of a ridge, or series of ridges at the surface, and a downward protuberance, several times greater in vertical dimension, into the heavier rocks of the crust. For the mountain-making movement proceeds under control of the law of isostasy; and the deformed mass is at all stages in balance with the rest of the earth's crust.[5]

It is now necessary to consider briefly the general normal constitution of the earth's crust in continental and oceanic regions. On the basis of observation of those portions of it at present exposed at the surface, supplemented by seismological studies of the speed of earthquake waves at varying depths, the crust has been regarded as composed of two main layers: an upper one, generally exposed at the surface of the continents, called the *sial*, and a deeper one called the *sima*. Each of these is further subdivided into two parts. The sial comprises an upper "granitic" layer about 12.4 km thick, having a specific gravity of about 2.6, and a lower dioritic layer about 18.6 km thick, having a specific gravity of about 2.8.[6] The total approximate thickness of the sial is thus 31 km, and its mean specific gravity is 2.72. The sima includes a layer of basalt of limited thickness immediately below the sial having a specific gravity of 3.05, and beneath the basalt a layer of dunite of indefinite thickness and specific gravity of 3.3. There is no sial under the open Pacific Ocean, and the bottom of the basalt is there at a depth of 46.4 km below sea level. If we take the mean depth of the Pacific as 5 km, then the thickness of the basalt in that stable region is 41.4 km, and the relative weight of a column, per unit of surface area, extending down d kilometers below sea level into the dunite, is $5 + 41.4 \times 3.05 + 3.3(d - 46.4) = 3.3d - 21.85$.

The conversion of the deltaic depression into a geosyncline by compressive stress involves the underlying rocks of the trough in the same deformation. Thus the folded and crushed mass, which is depressed to support the new range in obedience to the law of isostasy, includes not only the sial but most probably, also, the basalt of the sima.[7] If this be so, then the entire complex mass, comprising both the elevated and the depressed portions, would have a mean specific gravity of about 2.83. Now, if we consider a great mountain range having a mean altitude of, say, 3 km, we may let d be the depth in kilometers below sea level to which its keel is depressed into the dunite. Its relative weight per unit of area then becomes $2.83\ (3 + d)$, and this is the same as the weight of the oceanic column found above for the same depth.

Thus $\quad 2.83\ (3 + d) = 3.3d - 21.85$
Whence $\quad d = 64.5$ km.

That is to say, for the mountain mass 3 km above sea level there is a thickness of 64.5 km of the same deformed mass below sea level; and the depth of its immersion in the dunite is $64.5 - 46.4 = 18.1$ km.

This depression brings the relatively light crushed rocks into a zone of high temperature, where they are melted into a magma. The mass of the rock thus fused does not change, but its volume increases; and the expansive stress thus created tends to burst the walls of the chamber in which the magma finds itself. Upwards cracks are formed into which the magma flows till equilibrium of pressure is again established. The isostatic equilibrium of the column as a whole is

[5] For a fuller discussion see "The Isostasy of Large Deltas." *Bull. G. S. A.*, 49: 401–416. 1930.

[6] Andrew C. Lawson, *Bull. G. S. A.*, 43: 364–5. 1932.

[7] Andrew C. Lawson, *Bull. G. S. A.*, 45: 1065 *et. seq.*, 1934.

not disturbed, since it neither loses nor gains mass. The magma eventually becomes, by freezing, the granite, monzonite and quartz-diorite so characteristic of the central part of great mountain ranges the world over. And the magma which escapes upward by way of the cracks becomes the material of the satellitic bodies, such as dykes, sills and laccoliths, which invariably accompany the main granitic mass of every great range.

As soon as the new range appears, even as a preliminary ridge, above sea level it passes into the zone of erosion and begins to suffer degradation; the load removed is in part carried away by the rivers to the sea, and in part deposited as alluvial embankments upon its lower flanks. As long as the compressive stress of the earth's crust continues to operate for the upbuilding of the range, its rise may exceed the degradation. But when the compression ceases to operate for uplift, degradation becomes effective for the reduction of its altitude. The erosional removal of load, however, lightens the whole column, and it therefore slowly emerges from the heavy rocks in which its bottom is immersed. The amount of reduction of height is, therefore, not a direct measure of the mean thickness of the layer removed. The lowering of the surface is the thickness of the layer removed by erosion less the rise of the column by levitation. Although the mean specific gravity of the column, is 2.83, that of the sedimentary rocks at the top of it is about 2.67, the usually accepted figure, and for 1 km removed the rise is $\frac{2.67}{3.3} = .8$ km, so that lowering of the surface is $1 - .8 = .2$ km. Or, for a lowering of the surface 1 km the thickness of the layer removed is 5 km. In general, in the early stages of the degradation of the range, the mean thickness of the layer removed is five times the lowering of the surface caused thereby.

As the column, including the large body of molten magma at its bottom, slowly rises, the latter freezes to become the extensive mass of granite rocks we are familiar with in the central part of great ranges. These are exposed to our view by the stripping away of the cover of sedimentary, volcanic and metamorphic rocks, under which they were originally buried.

Although, as we have seen, the rate of lowering of mountain ranges is slow relatively to that of erosional removal, nevertheless they do disappear as major features of the relief of the earth's surface. In the later phases of their degradation, the rate of erosion diminishes steadily, due to the lowering of the grades of the streams and the failure of the lower relief to intercept precipitation from the atmosphere. Eventually the region where the range once stood as a majestic feature of the earth's surface presents no conspicuous relief. It becomes almost a plain at small elevation above sea level, and passes into the category of peneplains, of which there are many. As erosional removal diminishes asymtotically to nothing, the rise of the column, and therefore the rejuvenation of the relief, ceases. The causal mechanism of rise, relief of load, has stopped. The clock has run down, and the region is in static equilibrium.

From the foregoing discussion it appears that the following suppositions are justified as a coherent working hypothesis of the origin of mountains:

(1) **Mountain ranges consisting of folded sedimentary strata arise only in regions of excessive deltaic accumulation extending out into deep water.**

(2) **The depression of the sea floor under the depositional load, and the rise of the surface of the embankment to sea level by depositional accretion permit an accumulation having a thickness of about eight miles.**

(3) At this stage the depression of the crust under load begins to collapse due to compressive stress, and a geosyncline is initiated.
(4) The appression of the contents of the trough throws the strata into steep folds, the crests of which are lifted high into the zone of erosion, while the keel of the geosyncline is depressed several times as much into the sima, to secure support by flotation of the uplifted mass.
(5) In the high temperatures of the sima the keel is fused to a granitic magma, which is forced by expansive stress upward and outward, to make dykes, sills and other apophyses in the walls of the magma chamber.
(6) As erosion reduces the new mountain range the whole geosyncline, with its contained magma, rises by relief of load; and the magma eventually freezes to become a granitic batholith.
(7) The uplift is less than the mean thickness of the layer removed by erosion, so that ultimately the range may be, and normally is, reduced to a peneplain.

By way of concrete application of these general considerations we may review the geological history of the Sierra Nevada. The region where that range now stands was until late Jurassic time a portion of an extensive sea in which a great thickness of sedimentary and volcanic rocks had accumulated. In the fullness of time the depression, caused by this load of shallow water deposits, had so weakened the earth's crust that it collapsed under horizontal compressive stress, and the upbuilding of the range was initiated. As the result of a protracted process of deformation the strata were folded and the folds were closely appressed in nearly vertical attitudes. In the uppermost of these strata are fossils of marine organisms of late Jurassic age. Included in the deformation were the much older formations which entered into the makeup of the earth's crust beneath the floor of the Mesozoic sea and probably also the basaltic layer of the sima. The pressure was sufficient to shear large portions of the rocks affected and to induce in them the characteristics of dynamic metamorphism. A lofty range was the result, and this constituted a concentration of mass or a local addition of load upon the earth's crust. It is probable that this range was supported, as more modern mountain ranges are to-day, by the downward protrusion of the lower part of the deformed mass into the heavier rocks of the sima. The mountain range thus brought into being was much more extensive than the Sierra Nevada of today. After the uplift of the range and after the close appression of its folded strata and their dynamic metamorphism, the region of uplift was invaded by a granitic magma from below. The melt made its way upward partly by stoping, partly by fusion, partly by injection and partly by pushing aside the walls of its enclosing chamber. The effect of the melt on these walls was to impose a thermal metamorphism upon the already dynamically metamorphosed rocks. Without resort to pure agnosticism there is little escape from the conclusion that this magma resulted from the fusion of the bottom part of the column depressed into the hot region of the deeper sima. At a later stage the magma rose to higher levels in the crust with the emergence of the column induced by relief of load under erosion. There it crystallized into the granitic rocks so widely exposed throughout the Sierra Nevada to-day. The erosional process, which stripped the granite of its roof of metamorphic rocks, has left many remnants of that roof embedded in or resting on the granite. The embedded remnants have for the most part the vertical attitude of roof pendants, plunging into the granite. These are well exemplified in the vicinity of Mineral King. Others lie in flat attitudes upon the top of the granite, as on Mt. Dana, and on the crest to the west of Carson City. These indicate that the mean exposed surface of the batholith

is but little below the present position of its original top.

When erosion had thus stripped away most of the roof of the batholith, and had exposed its extent very much as it is to-day, the general surface had been so lowered that the summit of Mt. Whitney was only 4,000 feet above sea level. Since then the Sierra Nevada has been uplifted to its present position through 10,500 feet. This rise of the range comprised three distinct movements. The first is measured by the difference of altitude of the two terraces, the Subsummit Plateau and the Chagoopa Plateau, which is .91 km. The second and third movements together are measured by the difference of altitude of the Chagoopa Plateau and the local base level of erosion at which it was formed, and this amounts to 2.29 km. Of this rise only .33 km, the second movement, can be accounted for by erosional levitation. The balance 2.29–.33 = 1.96 km, recognized as the third movement, remains to be accounted for. The only way of doing this is to invoke the operation of the same compressive stress that gave rise to the range in the first instance. In that case crustal compression was applied to a great thickness of incompetent strata sunk in a broad trough, and they yielded by folding and mashing together to form the initial range. In the case we now have to deal with the same compressive stress was applied to a massive buttress of granite which could not fold, but could yield only by breaking and shearing. So the granite broke, and was sheared in such a way as to lift the range 1.96 km higher than it was before the break occurred. This means that the lower part of the granite mass was thrust westward under the upper part on an inclined shear plane; producing an effect as if the upper part had been thrust eastward over the lower.

One direct result of this thrusting was to thicken the granite throughout the extent of the range, and so greatly increase the load on the earth's crust. The additional load could be supported without very notable disturbance of isostatic balance only by the downward protrusion of the thickened batholith into the heavier rocks of the sima. Not only was the load supported, but the surface was raised by flotation 1.96 km. Part of the thickening was taken up in this elevation, but the greater part in the downward protrusion into the sima. The amount of the thickening appears from the following considerations: The mean altitude of the summit region of the Sierra Nevada to-day is about 3.08 km. Before thrusting set in its mean altitude was 3.08–1.96 = 1.12 km. To float a batholith of specific gravity 2.83 to this height above sea level it must have had a thickness of 54.35 km and have been immersed in the dunite 6.83 km. To float the thickened batholith to its present mean height of 3.08 km. it must have a thickness of 68.11 km and be immersed in the dunite 18.63 km. The difference between the two thicknesses, 68.11–54.35 = 13.76 km, is the measure of the thickening by the thrust movement.

The conclusion thus arrived at, that the Sierra Nevada as we know it to-day, owes its last important uplift of 1.96 km to a thrust, which thickened the batholith and caused it to float higher, necessitates a revision of our notions of the fundamental structure of the range. The current conception among geologists is that the eastern front of the range is the degraded scarp of a zone of normal faulting. It is supposed that after the region had been reduced by erosion to comparatively low altitude and subdued relief, it was dislocated from the country to the east and tilted up on a normal fault, dipping eastward, the face of which now overlooks the deserts of Nevada. A reciprocal down-

ward drop to the east of the fault is of course not excluded from this hypothesis. But this notion fails to supply any mechanism for the uplift of the mountain block. Thrusts are common features in the crust of the earth, some of them of great magnitude. They always necessarily thicken the crust; and if the region affected be large enough, so that the rigidity of the crust is inadequate to support the increase of load, the thickening causes the crust to float higher, so as to preserve isostatic balance. There are numerous normal faults along the eastern front of the Sierra Nevada, but that front is not fundamentally the scarp of a normal fault. It is the edge of a thrust block, and the underlying thrust plane, on which the block rides, is due to emerge in the bottom of the alluvium-filled valleys at the foot of the steep eastern slope. The normal faults are secondary features, significant of minor gravitative adjustments, necessitated by the thrust movement. It would be difficult to visualize the locus of emergence of a great thrust free from secondary normal faults.

It is perhaps worth noting in conclusion that, if the thrust plane on its downward dip under the region of the Great Valley, intersected and thickened the heavy rocks of the sima, the column embracing the thickening of that portion of the crust would be abnormally heavy and would sink. If the incorporation of the excess heavy rock into the general body of the sima be a slow process, the initial uplift of the surface might be removed by erosion before it was accomplished; and, when the subsidence of the column was finally effected, there might be a depression of the surface above the zone of original thickening, a structural valley, which would become a trap for sediments and so have the general characteristics of the Great Valley of California.

THE HORMONES AND VITAMINS OF PLANT GROWTH

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THE phenomenon of plant growth has a very intimate bearing upon many of the activities of mankind. In fact, the very existence of man, and of animal life in general, depends in the last analysis upon the vegetation of the world. Plant growth has, therefore, been the subject of study by man for many centuries. The investigations of the past have dealt primarily with the effects of various external factors on plant growth and development, and the influence of such factors as light intensity, temperature, fertilizer, etc., has been studied. For each plant there is an optimum combination of these external factors. Given this optimum combination, there are, however, still other factors and in particular ones inside the plant, which limit its growth. We say that the growth of the plant under these optimum external conditions is limited by "internal factors."

A knowledge of these "internal factors," what they may be and how they operate, is of course necessary before we can hope to control plant growth according to our desires. It is only during the past ten years that significant advances in the understanding of this problem have been made. We now know that some of these internal factors are special chemical substances that are present in the plant and which regulate its growth just as the special chemical substances of the pituitary gland regulate the growth of the human being. In this article we shall survey some of the experimental methods and review some of the results of the work on the hormones of plants. Much of the work has been done by the plant physiology group at the California Institute of Technology although the work of other institutions will also be discussed.

It would be well to make clear at once what is meant by the terms "hormone" and "vitamin." Almost 60 years ago, Julius Sachs, the father of modern plant physiology, came to the conclusion, based upon theoretical considerations, that effects of one part of the plant upon other parts, the "correlations" within the plant, must be ascribed to individual chemical substances. These substances, Sachs reasoned, must be present in very minute amounts, but must have effects out of all proportion to their relatively low concentrations. Sachs also clearly differentiated these substances from the ordinary "foods" which are substances present in relatively large amounts, and out of which the bulk of the plant may be built. Some 25 years later it became clear that specific chemical substances function also in animals as "chemical messengers," connecting the activities of one organ with those of other organs. To such substances Starling in 1904 gave the name of *hormone*. A hormone is then essentially a substance which is produced in one part of an organism, is transferred to another part, and there, in very minute amounts, influences a specific physiological process. A hormone is, as its name implies, a chemical messenger, which "tells" other parts of the organism how they must respond.

The vitamins, on the other hand, are specific chemical substances which are needed by the animal body, but which the animal body is unable to make. Animals are fortunately able to obtain these necessary substances from plants, many

of which are able to synthesize vitamins as by-products of their photosynthesis. A vitamin, like a hormone, is needed in the body for specific physiological processes. A hormone, however, is produced in particular organs of the body itself. A vitamin, on the other hand, must be supplied from the outside; must be supplied with the food.

The distinction between a hormone and a vitamin is not by any means sharp. A substance which is a hormone for one organism may be a vitamin for other organisms. Thus ascorbic acid (vitamin C) is not formed by most higher animals and must be supplied to them. The rat, however, is able to produce ascorbic acid in its own liver, and this substance is then really a hormone for the rat.

The striking manifestations of plant growth, such as the spectacular growth of a seedling or the unfolding of a bud, are due to an increase in size of cells. The increase in size of plant cells is controlled by a number of internal factors but chief among these is a specific chemical substance, a hormone, known now as auxin. Let us consider a few of the experiments which show how auxin is formed in the plant and see how it influences growth.

When an oat seedling grows, its leaves are surrounded by a hollow sheath known as the coleoptile. The coleoptile elongates from a length of one or two mm. to almost four cm, during which time only a few cell divisions take place. Its growth is almost purely by cell elongation. It is therefore a suitable and convenient object for the study of cell extension, and has been used a great deal in the study of auxin. The oat coleoptile does not grow at the extreme tip and it does not grow at the extreme base. It grows rather by elongation of a zone near its middle. If the tip of the oat coleoptile is removed, that is, if the coleoptile is "decapitated," the growth rate of the remaining portion quickly drops to a low value. If, however, the tip is replaced on the "stump" immediately after it has been removed, the growth rate of the coleoptile is not greatly retarded. The tip exerts an influence on the growth of the lower portions of the coleoptile, and this effect can be transmitted across a cut surface. It may even be transmitted across a thin sheet of gelatin inserted between tip and coleoptile stump. If the coleoptile tip is removed and then placed on one side only of the coleoptile stump, the growth effect is transmitted only down one side. This side grows more than does the other, and as a consequence, the coleoptile bends. The demonstration that the effect of the coleoptile tip on growth is due to a growth hormone is, however, due to a classical experiment of Prof. F. W. Went in 1927. A coleoptile tip is removed from a plant and placed on a small block of agar for a time. The tip is then removed from the agar, and the agar applied to the stump of a decapitated coleoptile. These agar blocks are able to bring about growth just as were the original tips themselves! The effect of the tip may be made to pass into agar, and from the agar back into the plant. From this experiment it is a safe inference that the growth effect is due to some chemical substance.

A simple and quantitative method of determining the "growth substance" may be had by the application of an agar block, containing the growth substance, to one side of a decapitated coleoptile. The coleoptile grows more on the side with the agar block than on the other side, and the resulting curvature is proportional to the amount of growth substance in the agar block. If rigidly standardized conditions are adhered to, this method may be used for the quantitative determination of the growth substance. It is in fact possible to use this test so effectively that concentrations of growth substance may be determined to within 5 per cent.

We now know that only very small

amounts indeed of this chemical growth substance are present in coleoptile tips. If 20 people were to do nothing but cut the tips from seedlings, so that these tips could be used for the isolation of the substance, these 20 people would have to cut steadily for about 125 years to obtain 1 gram of the hormone. Interestingly enough, however, there are relatively large amounts of the substance present in human urine, and two organic chemists in Holland, Prof. Fritz Kögl and Prof. A. Haagen-Smit, began several years ago to isolate it. At every step in the fractionation procedure they used the oat-bending test to determine quantitatively into which fraction the "activity" had gone. In this way they were able, after they had concentrated the material approximately 100,000 times to isolate a crystalline substance of which approximately 2×10^{-11} grams sufficed to give a 10 degree curvature of an oat coleoptile. Kögl and Haagen-Smit have isolated less than one gram of this crystalline substance, yet even with this small amount they were able to work out its chemical structure. Kögl gave this substance the name *auxin,* or more particularly auxin-a, since there is a closely related substance differing by the elements of one molecule of water which is called auxin-b.

Shortly after the isolation of auxin-a, the isolation of still another active substance was announced. This substance also possesses great activity in the oat test, *i.e.,* is capable of causing bending of the oat coleoptile in amounts about twice as great as those of auxin-a which are needed. This substance is a well known substance, indole-3-acetic acid. Indole acetic acid apparently possesses all of the effects upon plants which auxin-a possesses, but it does not occur naturally in higher plants. It is formed rather by bacteria and molds as a by-product of their metabolism. Indole acetic acid is now, however, readily available since it can be easily synthesized in the chemical laboratory. This discovery of indole acetic acid has opened to the physiologist the possibility of experimenting directly with one of the internal factors of plant development.

The work discussed thus far has dealt only with the oat seedling. However, it is necessary to stress again that auxin regulates cell elongation in other organs and in other plants. In all of the higher plants thus far carefully examined, in the growth of veins of leaves, of petioles, of flower stalks, of stems in general, auxin is present and regulates growth just as it does in the oat coleoptile. Auxin even influences the growth of such simple plants as the uni-cellular algae.

The way in which auxin acts on plant cells to bring about this general increase in size is not yet completely understood. It is known, however, that one end result of the action of auxin is increase of the extensibility of the cell wall which covers the surface of every plant cell. The plant cell in many ways resembles a balloon which is blown up with water pressure rather than with pressure of a gas. Auxin makes the balloon more extensible so that it can expand more rapidly.

We might next examine a few of the other plant growth phenomena that are regulated by auxin. The phototropic and geotropic movements of plants, that is, the movements by which plants assume favorable positions with respect to light and to gravity, are all growth responses. If light falls on one side of a plant this illuminated side grows slower than does the non-illuminated side and the plant as a result bends toward the light. This is almost wholly due to the redistribution of auxin within the plant as is shown by the following experiment. A small cylindrical piece of stem is taken, and at the top is placed an agar block containing auxin. At the bottom are placed two blocks which do not contain auxin and which are separated by a razor blade. Such an arrangement is allowed to stand

for one hour. The bottom blocks are then removed and placed upon oat seedlings, and their auxin contents determined by the curvatures which are produced. If the original experiment was carried out in darkness, the two bottom blocks are found to contain equal amounts of auxin, just as would be expected. If, however, light is allowed to fall upon one side of the stem section during the experiment, it is found that the block under the illuminated side contains less auxin than that under the non-illuminated side. Under the influence of the one-sided light, then, auxin, during its downward transport, has moved from the light side to the dark side. This also happens in the normal plant. As a consequence the non-illuminated side, with its greater amount of auxin, grows faster, and the plant curves toward the light. The response of plants to the force of gravity is quite similar in principle. When a plant is placed in a horizontal position auxin moves from the upper to the lower side of the stem. As a consequence the lower side grows faster than does the upper side and the plant curves upward to regain its normal vertical position.

Dwarf growth habit in plants is sometimes also an auxin phenomenon. In corn, for example, there are a number of dwarf races known, each one of which depends upon a single recessive genetic character. The case of one of these dwarfs, known to corn geneticists as "nana," has been studied in detail. Nana plants differ from the normal in that the stems are very short. The leaves, however, are approximately normal. As the result of the short stems, the leaves appear to be crowded in a rosette. It is now clear that these dwarf corn plants are dwarf because they lack sufficient available auxin. Although nana plants produce almost as much auxin as is produced by normal plants, the activity of oxidizing enzymes in nana plants is much greater than that in the normal, and as a result the nana plant destroys, oxidizes, its own auxin very rapidly, so that in such plants very little auxin reaches the rapidly growing portion of the stem. If nana plants are properly treated artificially with large amounts of auxin they are able to grow quite as well as are normal plants. In this case, also, we are able to say a little about the manner in which a genetic factor, a "gene," exerts its effect. The gene "nana" causes an increased oxidizing enzyme activity, this in turn causes an increased destruction of auxin, this leads to auxin deficiency in the plant, and the plant is then dwarf.

Plants which grow at high elevations, for example in mountainous regions, are known to be in many cases of smaller stature than related plants growing at lower elevations. There are probably many influences which contribute to this "high altitude dwarf growth," but one of these factors, also, is related to auxin. Auxin is destroyed by ultra-violet light and it seems probable that plants grown in high regions with the attending higher intensity of ultra-violet light, suffer from auxin deficiency, just as do plants experimentally irradiated with ultra-violet. Some of the dwarf plants of mountain tops may then be "auxin deficiency dwarfs" just as are corn plants which carry the genetic characters for dwarf growth.

One other function of auxin in the plant might be mentioned here, namely, its rôle in bud inhibition. From early times it has been known that the lateral buds (the buds at the base of each leaf) usually do not develop in the presence of a terminal bud. If, however, the terminal bud is removed, as for example when a shrub or tree is pruned, some of the lateral buds grow out at once. We say then that a terminal bud "inhibits" the lateral buds. This problem was attacked by Prof. K. V. Thimann and Dr.

F. Skoog. They showed that the terminal bud is the most active auxin producing center in the plants with which they worked, that is, in peas and beans, and that the dormant lateral buds produce almost no auxin. If, however, the terminal bud is removed, the lateral buds immediately commence to produce auxin and consequently to grow. Agar blocks containing auxin were then applied to plants whose terminal bud had been removed. The artificially applied auxin inhibited the growth of the lateral buds quite as well as did the normal terminal bud, and they therefore justifiably concluded that it is the auxin secreted by the terminal bud which causes inhibition of the lateral buds. This mechanism of bud inhibition has been shown to hold for many different kinds of plants and is apparently quite general. It is also of interest that many dwarf races such as those of peas and beans, etc., tend to have a bushy habit, that is, that they tend to have extensive development of their lower lateral buds. This is quite possibly due to the same cause as the dwarfing itself, namely to the low auxin concentrations present in the dwarf plant. Not only is there not enough auxin present to suffice for normal growth; there is also not enough auxin present to cause normal bud inhibition.

Only the growth of stems and of buds have been considered thus far. It is now time to turn attention to that retiring but important part of the plant, the root. Auxin does not in general stimulate root growth, and in fact the concentrations of auxin which stimulate the growth of stems are very inhibitory to the growth of roots. There must be then other hormones which are necessary for the growth of roots, and a program for the elucidation of these hormones was embarked upon. Hormones which affect the growth of the root should come either from the upper parts of the plant or from the soil. In order to study these root growth hormones the root should be isolated from these two sources of supply. It is then possible to determine what substances we must "feed" the root in order to make it grow. A short root tip of a pea seedling is cut from the plant. This root tip may be grown in a glass vessel as an isolated root if the proper nutrient solution is supplied. By a long series of experiments a nutrient solution was determined which would permit isolated root tips to grow 1 cm or more per day, that is, to grow even faster than they do when they are attached to the normal plant. This nutrient solution contained only the ordinary "food" substances such as salts and sugar. A second short tip may be cut from such an isolated root that has grown for several days. This "second generation" root tip grows but very little if it is placed in nutrient solution. If still a third time a tip be cut from the root and placed in fresh nutrient medium, it does not grow at all. The original root tip must have contained some substance which is needed for the growth of roots and which is gradually used up so that the isolated root is not able to grow indefinitely in this solution containing only ordinary foods. The problem now was to find out what this substance might be.

If a very small amount of yeast extract, 0.01 per cent. or less of water extract of yeast is added to the medium in which isolated roots are grown, the roots are able to grow for many months at a rate of 1 cm or more per day. Fresh tips may be cut from these roots weekly and placed in fresh nutrient solution, but if the solution contains this small amount of yeast extract in addition to the ordinary foods, the roots grow almost as well as do normal roots which are attached to the plant. There is then something in yeast extract which is essential for the continued growth of the root, and experiments were made to determine the chemical nature of this something.

Fortunately it soon became clear that the substance was associated with the vitamin B complex of yeast, and tests were made with crystalline preparations. The root growth factor was found to be identical with vitamin B_1, the anti-neuritic or anti-beri-beri vitamin, a substance whose chemical structure and synthesis had been finally worked out a few months before by Prof. R. R. Williams, and which is a rather peculiar substance containing the heterocyclic thiazole ring, not before known to occur in nature.

It is appropriate to note here the peculiar status of the vitamins as far as plants are concerned. At the end of the 19th century Eijkman first showed that the anti-neuritic vitamin occurs in large amounts in seeds, and there has since been abundant data collected as to the universal occurrence and distribution of the several vitamins in plant material, in seeds, leaves, stems, roots, and even flowers. However, it seems to have been tacitly, although very generally, assumed, that the plant produces these substances as a sort of a friendly gesture toward the animal world, that vitamin B_1 was produced by plants so that animals would not get beri-beri. This assumption was of course false, and as we shall see, the vitamins, not only vitamin B_1 but the other vitamins as well, are produced by plants because they play important rôles in plant development, and they are stored in seeds because they are needed for the growth of the seedling plant.

Now that we know that vitamin B_1 is necessary for the growth of roots, it is possible to understand why the tips which are freshly cut from the seedling plants are able to grow even in nutrient solution which does not contain the vitamin. Root tips freshly cut from the plant contain quite large amounts of vitamin B_1, and hence are able to grow well even if more is not added to them. Tips taken from the isolated roots after they have grown contain, however, much less vitamin B_1 and are limited in their growth by this substance. Tips from these "second generation" roots contain no detectable amount of vitamin B_1. These tips if they are examined with the microscope give a very interesting clue as to the way in which vitamin B_1 affects root growth. In these vitamin B_1-free roots there are few if any cell divisions. The cells which are present elongate, mature, deposit starch, and differentiate into the various root tissues in an approximately normal fashion. These processes then do not depend greatly on vitamin B_1. The cell divisions of the root tip, however, depend upon the presence of the vitamin. Whereas auxin, the stem growth hormone, influenced cell elongation, vitamin B_1, the root growth factor, influences cell division.

The amounts of vitamin B_1 which are needed by the root are very minute. The normal pea root tip contains only about one ten-millionth of a gram of the vitamin. The amounts of vitamin B_1 which just cause a detectable effect upon root growth are still less than this. For example, a solution which contains 1×10^{-11} grams of vitamin B_1 per liter still causes a measurable effect upon root growth. One gram of vitamin B_1 would suffice for the growth of a root at least 1200 miles long!

Vitamin B_1 is not only a growth factor for pea roots. On the contrary, it is a very general growth factor for roots. Of the many plants thus far examined not one has failed to respond to this substance with increased growth of roots.

In the normal plant vitamin B_1 is formed in the green leaves. From the leaves it is transported to the roots where it exerts its effects upon root growth. In the normal green plant vitamin B_1 is therefore a plant hormone just as is auxin. It is a substance which is produced in one place and is transported to

another where it exerts its effect. The isolated root, however, can not obtain its vitamin B_1 supply in this way and this substance must therefore be supplied in the nutrient solution with which the root is fed. Vitamin B_1 is a *vitamin* for the isolated root.

Up to this point we have considered what may seem very academic aspects of the internal factors controlling plant development. Let us now consider some of the practical ways in which this knowledge can be applied. One of the ways is in that classical horticultural problem, the rooting of cuttings. The rooting of cuttings has always been a very empirical procedure. Cuttings of some plants root spontaneously when the base of the cutting is placed in moist sand. It has never been possible to root the cuttings of many other plants. Several years ago an investigation of the internal factors involved in the production of roots on cuttings was taken up. It was found that there is something produced in leaves and in buds which is able to cause the initiation of "root primordia," that is, of embryonic roots, at the base of the cutting. On some cuttings these embryonic roots grow out into visible roots, and we say that the cutting has "rooted." It was also found that there is a something, different from the first, which is necessary for the growing out of these embryonic roots. This second substance comes from the leaves. The chemical nature of the substance which is needed for the initiation of roots was next investigated. To the great surprise of everyone, this substance soon turned out to be identical with auxin! The effect of auxin on initiation of roots is of quite a different nature from its effect on cell elongation, and to discuss the reasons for it would lead us too far afield. However, the fact is that auxin, through its interaction with still other internal factors, is able to cause the initiation of embryonic roots on cuttings of a great many different kinds of plants. This fact has been made use of in horticultural practice upon wide scale, and auxin is now sold to the public for this purpose under a variety of trade names.

Auxin treatment, as has been explained already, affects the initiation of embryonic roots. What the horticulturist desires, however, is well-developed, well-grown roots. With many cuttings auxin causes the initiation of embryonic roots, but these fail to develop further. Even with favorable plants only a fraction of the root primordia which are initiated actually grow out. It has also been observed that cuttings taken at what are called "unfavorable" times of the year, for example immediately after very cold weather, fail to develop many visible roots after auxin treatment. Embryonic roots are formed by the auxin treatment but these fail completely to develop further. All of these facts point to the need of treating cuttings with a root growth factor. When vitamin B_1 was found to be such a root growth factor, it was immediately used to aid in the rooting of cuttings.

Experiments were made in which cuttings of plants which are notoriously difficult to root such as some of the Camellias, were treated at the base with auxin in the usual way. Embryonic roots developed on these cuttings after several days. Then the cuttings were treated with vitamin B_1. Within 24 hours the embryonic roots began to grow out, and in a few days the cuttings had many long roots. The results of this "double treatment" are often spectacular. Healthy, well-rooted cuttings can be obtained within two to four weeks, of many plants which it has not been possible to profitably propagate from cuttings before.

With plants whose cuttings normally produce some visible roots after auxin treatment, the rooting can often be improved by application of vitamin B_1. A

good example of this type is the lemon cutting. In fact, no plant which has thus far been investigated has failed to at least improve the rooting of its cuttings with vitamin B_1 treatment, indicating again that this substance is a very general factor for root growth.

It is of interest to note that the differences in the rooting of cuttings, taken at what gardeners call "favorable" and "unfavorable" times of year, tend to disappear when cuttings are rooted with this combination of factors for root initiation and root growth. Thus even leafless hardwood cuttings can be successfully rooted, with plants which otherwise would not root at all. It seems probable that the differences in the ease with which cuttings root spontaneously at different times of year are due in the first place to seasonal differences in the amounts of auxin and vitamin B_1 present in the cuttings when they are cut from the plant.

The rooting of cuttings has now been put on a rather exact basis as a result of these investigations of the internal growth factors which are involved. There are other ways in which plant growth can be controlled by the use of these factors, but only one need be mentioned here. In the past few years there has been much interest in the growing of plants under carefully controlled conditions, with their root systems either in a mineral nutrient solution, or in washed sand watered with nutrient solution. Plants grown under such conditions of "tank culture," "hydroponics," or of sand culture, develop under optimal or near optimal external conditions and may give very large yields. Their growth under these optimal external conditions is, however, limited by internal factors, and for any further improvement in their growth an attempt must be made to find what internal factor is limiting. Recent experiments have shown, in fact, that some plants in tank or sand cultures may be accelerated in their development by the application of vitamin B_1 to their culture solution. These plants apparently do not produce in their leaves as much vitamin B_1 as the roots can use. Accordingly, the root system is limited in its development by this internal factor, and shoot development is limited by root development, as we shall shortly see in another connection. Application of vitamin B_1 should allow the roots to grow more vigorously and accordingly shoot growth to be also improved. Needless to say, it is not expected that all plants are limited by vitamin B_1; different plants are undoubtedly limited by different internal factors, but it seems reasonable to suppose that it is along this line that further improvement of tank culture crops must proceed.

The internal growth factors which have been most extensively studied and which are at present best understood are auxin and vitamin B_1. There are, however, many other factors of this type. There is, for example, the substance given off by injured cells which is responsible for the healing of wounds as well as for abnormal growths of various kinds. The chemical nature of this substance has been investigated but its chemical structure has not yet been worked out in detail. Perhaps the most general and most interesting test for plant growth factors is, however, the "isolated embryo" test. In this test, the embryo is removed from the seed so that it is unable to obtain either the food or the growth factors which are stored there. The aseptic embryo is then placed in a sterile flask containing nutrient solution. This solution contains sugar from which the plant is able to derive the energy necessary for its metabolism, and in addition the solution contains all of the necessary mineral salts. The embryo is allowed to develop in this medium in the dark. The embryo, under these conditions, is completely dependent on the

medium both for food and for special growth factors. The ordinary foods, however, are all supplied in the nutrient solution in amounts sufficiently large to be non-limiting. The growth of the embryo is then limited only by the special growth factors in the medium. As one can readily see, this is a very general and delicate test for the substances necessary for plant development. Very extensive experiments of this kind have been carried out with the isolated embryo of the pea. If no special growth factors are added to the nutrient solution, the embryo grows into a dwarf plant approximately 1.5 cm high. That it is able to grow at all is due to the fact that the embryo when it is cut from the seed already contains a certain amount of each specific growth factor. In order to make this plant grow more, we must now try to give to it, in the nutrient solution, the growth factors which it normally gets from the seed. If vitamin B_1 is supplied, the root growth of the young plant is very considerably improved. The amount of vitamin B_1 which is necessary to bring about this effect is of the same order of magnitude as that normally present in the pea seed. At the same time, the stem growth of the plant is greatly improved. Vitamin B_1, however, has no detectable influence upon the growth of isolated stems, and it seems reasonable to conclude that its effect upon the growth of the stem must be indirect and due to its effect upon the growth of the roots. The roots grow much better when vitamin B_1 is supplied and as an indirect result of this the stem also grows better. Vitamin C, ascorbic acid, also, is a growth factor for these isolated embryos. Vitamin C must be absorbed by the embryo until it reaches approximately the concentration which is present in the normal plant in order for it to exert its maximum effect in increasing the growth of the isolated embryo. Finally, pantothenic acid exerts an influence upon these embryos. Pantothenic acid is one of the group of "bios" factors that is necessary for the growth of yeast, but it also is present in the pea cotyledon and appears to function in some rather direct manner on the growth of the seedling shoot. Still others of the known "biologically active" substances influence the growth of excised pea embryos. Vitamin B_2 and nicotinic acid, two other substances of the vitamin B complex, have such effects and are undoubtedly to be regarded as plant hormones although their specific functions have not as yet been worked out. Theelin, one of the female sex hormones of animals, should also be mentioned in this connection. It has been known for some time that substances having oestrogenic activity are present in plant material, in leaves and in seeds, for example. In fact, when this was first discovered it was suggested that the oestrogenic substances might function in some way in regulating the reproductive processes of plants. This undoubtedly is not so, for it is in general not possible to bring a plant into flower by applying oestrogenic substances to it. However, there is abundant evidence that theelin is able to improve the vegetative growth of plants under some conditions. It is stored in seeds, and consequently one might well suspect it of being necessary for the growth of seedlings. In fact, it is quite potent in improving the growth of the plant in the isolated embryo test. If several of these individual growth factors are combined, the embryos grow somewhat better than they do with only one of the growth factors. However, there must be still other, as yet unrecognized factors, involved, for we are not yet able to duplicate *in vitro* the growth of a normal pea seedling. It seems safe to prophesy, however, that as we seek for these other growth factors, using this test which appears to be so far

removed from practical problems, we may nevertheless learn still a great deal more about the ways in which plant growth may be controlled under practical conditions.

One example of what might be done with even a small knowledge of the bud growth factors may be mentioned. The peach tree, like many other deciduous trees, requires a certain amount of winter "cold treatment" if it is to resume its normal growth the following spring. In warm climates such as that of Southern California the winters are often not sufficiently cold to furnish a satisfactory cold treatment, and as a result the buds of peach and of some other trees fail to open at the normal time in the spring. This is known as "delayed foliation" and may often be so extreme as to cause considerable losses. This is a problem in failure of buds to grow. It is not a problem concerned with the usual foods because chemical analysis has shown that there are large amounts of food present in the dormant twigs. It might be supposed that it is a problem related to the specific growth factors, and this seems indeed to be the case. Dormant buds can in some cases be caused to resume their growth if they are supplied with those growth factors which, as we saw earlier, affect the growth of the isolated embryo. It may perhaps be predicted that through a knowledge of these internal growth factors dormancy may be completely controlled.

In this article a few of the results of the investigation dealing with the internal factors involved in plant development have been discussed. To sum up: The growth of stems can be regulated to a considerable degree with the aid of auxin. Internal factors other than auxin play a rôle here, however, and one can not yet say that stem growth is completely under our control. Root growth, on the other hand, is relatively well understood. Not only root growth itself but the formation of roots can be regulated rather exactly. This, however, is as far as the study of the internal factors in plant development has progressed. The general line of attack which it is necessary to make upon this type of problem is, however, clearly understood and progress in the future will be much faster. There are many problems, problems outstanding both because of their practical and their theoretical interest which can now profitably be attacked; for example, that of the initiation of buds, of growth in thickness, of leaf growth, and of fruit development. In all of these cases it seems well indicated that special substances, hormones, or more generally, special growth factors, are involved, and that much might be elucidated by an appropriate "hormone attack." The problem of dormancy also gives promise, as has just been indicated, of being a problem involving special internal growth factors. Flower bud initiation and the growth of flowers are practical problems of the first importance which are yet to be studied from this point of view. The study of the plant hormones is admittedly still in its infancy, but it is a study which holds bright promises for the future.

SCIENCE AND SOCIAL VALUES

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THE distinguished pharmacologist, John J. Abel, has stated his ideal in a sentence: "Greater even than the greatest discovery is to keep open the way to future discoveries." In other words, nothing should be allowed to stand in the way of scientific advance. Personally, I would rather alter this statement to read: Greater even than the greatest discovery is to make proper use of discovery. This is not very different from the instructions of Saint Paul: "Prove all things; hold fast to that which is right." Thoughtful people are apprehensive about the misuse of Science.

According to Raymond B. Fosdick, president of the Rockefeller Foundation: "Humanity stands to-day in a position of unique peril. An unanswered question is written across the future: Is man to be master of the civilization he has created, or is he to be the victim? Can he control the forces which he has himself let loose?"[1]

And the Nobel prize winner, Alexis Carrel, has written: "The enormous advance gained by the sciences of inanimate matter over those of living things is one of the greatest catastrophes ever suffered by humanity. The environment born of our intelligence and our inventions is adjusted neither to our stature nor to our shape. We are unhappy. We degenerate morally and mentally."[2]

Dean G. S. Ford, at the moment acting president of the University of Minnesota, has approached the problem as an educator. He is concerned with the kind of science which is fed to the people of the United States. He says: "Nobody today needs to have his intellectual gullet enlarged so that he can swallow more unbelievable marvels of science. We do that now without batting an eye. What keeps us socially and individually retching and in distress is the string tied to science and the things it drags along with it . . . our gorge rises now, meaning our prejudices, intolerances, accustomed and inherited ways of thinking and acting, so that there are people who would have society stick its finger down its throat and get rid of science, at least temporarily."[3]

Harold G. Moulton, president of the Brookings Institution, tells us very concisely for what science is blamed: " . . . for developing an industrial organization of such vast complexity as to baffle human control; for creating an international economic structure in a world of political nationalism; for building implements of warfare which threaten the very extinction of peoples; for so mechanizing work processes, as to dull the qualities of human intelligence; for changing the relative rates of population growth in the upper and lower strata of society; for bringing into existence new forms of goods and services in such rapid succession, and in such profusion as to make it difficult for slowly changing human beings to assimilate them; for giving us leisure that we do not know how to use; for producing chronic unemployment and the grave social problems which it entails; for building up a capacity for production beyond our powers of consumption; for creating an artificial way of life in place of the old simplicity; and for distorting ethical values and undermining religion and morals."[4]

1 H. G. Moulton, *Science*, February 25, 1938.

2 *Ibid.*

3 B. C. Gruenberg, "Science and the Public Mind." New York: McGraw-Hill Book Company, 1935, 196 pp.

4 H. G. Moulton, *loc. cit.*

This arraingnment of science is breathtaking. But we all know that science is a kind of two-edged tool which can cut both ways. An immense amount has been said and written about the use and misuse of science. Obviously, in the short time at our disposal, we can but scratch the surface. No two people would do so in the same way. We shall limit ourselves to five ways in which our social body politic feels the impact of science.

(1) It is natural to think first of *unemployment*. Even the most learned understand this but imperfectly. Men and women in many occupations are being displaced by machines. This is happening, for instance, as a consequence of the installation of labor-saving machinery in steel rolling mills. Since 15 men are thus enabled to do more than 1,200, it is estimated than 85,000 will be permanently displaced within three years.[5]

Each great labor-saving device may be a step forward in social values, but we would rather have it without this social dislocation in its wake. It is said that the maladjustment is corrected by the development of other new industries which absorb the unemployment. While this statement may have some basis in fact and be a sort of half-truth, it carries with it a lot of wishful thinking. There is a parrot-like quality in its insistent repetition—a sort of defense reaction. As science advances, new industries are developed which take up part of the slack, but unemployment on the whole tends to increase. The shock of the utilization of each invention should be considered on its own merits unobscured by doubtful generalizations. When 10,000 men, who have done their duty over many years and have earned a fair living for their families, are deprived of the jobs in which they have become proficient, and this almost without warning, exactly what are they to do? These 10,000 may not happen to be in a locality where a new industry is developing. Even if they are, their training may not be such as to lead to their employment. They and their dependents are likely to experience a terrible jolt which will cause years of suffering. It is almost as bad, when industries move to another part of the country, nearer raw materials or cheaper labor, and leave the original workers behind.

This is of course a matter about which much could be said. There is a limit to which a minority must be protected at the expense of failure to make the fruits of science available to the majority at a price which they are fully able to pay. We shall revert to age and sex factors in unemployment later.

(2) Some assert that advances in science promote *mediocrity*. If any considerable number of laborers are to become mere button pushers, opportunity to cultivate skill and pride in accomplishment will be lost. Manual laborers on relief, numbered by the million, sometimes work in a rather half-hearted fashion, though there are, thank heaven, many exceptions. When the work is of remote, or even of no social value, the effect on them can not be described as uplifting or stimulating. It is given to them because of our belief in the right of all workers to a living wage. Whether they are good, bad or indifferent makes but little difference. We are unwilling to let the fit survive and to see the unfit go under. In labor we see a marked leveling.

And the same tendency is noticeable in education. This, beyond the acknowledged minimum of the three R's, like work, is the right of all whether they earn it or not. The tempo of mass-education is all too frequently adjusted to the dull and the stupid, even to the pathological, with whom the promising youngsters must keep step. Again the premium which used to be placed on

[5] Marquis Childs, *St. Louis Post-Dispatch*, March 6, 1938.

initiative and brains is going by the board. Science, however, is not so much to blame as our conception of relativity in social values.

(3) Mediocrity is partly due to *coddling,* which, from another angle, is definitely a result of advances in science. Thus, we are protected from disease by improvements in medicine; from changes in temperature by proper clothes, heating and, for the chosen few, by air conditioning; from having to use our muscles by all kinds of mechanical devices. We could mention many other ways in which our bodies are pampered while our minds are stimulated to a fever pitch. Our control of external environment is becoming so perfect that there is real danger of loss of God-given powers of adaptation through disuse.

Jennings has aptly said: "All organisms *must* protect themselves against the injurious forces of nature: against heat and cold and wind and wet; against starvation and overeating; against unfit food and drink; against bumps and bruises and broken bones; against plagues and poisons. That's what life is; a struggle for existence. If any organism ceased to struggle, ceased to select its environment, ceased to protect itself —its kind would become extinct in a generation. So it is with man, with bird, with fish, with worm, with protozoon, with plant."[6]

But unlike lower animals, as Darwin and numerous leaders since have told us, we prevent the operation of natural laws. We will not allow mankind to become extinct in a generation, but what the distant future holds for us if we rely more and more on machines and less and less on our bodies we can not tell. Such dependence does not make for progress.

(4) With labor becoming more mechanical, with reduction in hours and increased idleness there is no doubt that susceptibility to *propaganda* increases. This menace to freedom of thought and action is as old as history, but it comes to us with new and almost irresistible impetus.

Plato, in his discussion of tyranny, has given us a clear view of propaganda. "Tyranny is not so much a form of government as political death, or sleep during which all conscious exertion of power is extinguished. The people, like a vast mass of brute matter, are fashioned by their tyrant into whatever form he pleases: he sends jugglers among them, under the name of priests, who fill them with dreams favorable to tyranny; by the instrumentality of these men, he darkens their minds, stupefies them with intellectual mandragora, and gradually plucks up by the root every free and manly and noble sentiment; ultimately, with more than Circean art, he transforms them into hogs, rings their noses, and turns them to grunt, feed and fatten for his use in the sty of slavery."[7]

It is interesting to note that the principles of propaganda and of hypnotism are identical. They are to eliminate all thoughts which give balanced judgment, so that the force of the one remaining is so greatly enhanced that behavior is unconsciously determined thereby. Knowledge of the details of hypnotism, coupled with the onward rush of mechanical science, radio, movies, telegraph, etc., make propaganda a more potent force in shaping human behavior than ever before. In the hands of a dictator it is of all the most socially destructive influence of science. We, in great centers of learning, who enjoy a generous measure of freedom of thought and behavior, should be more resistant than others who are less fortunate. All too frequently we follow like sheep.

(5) The social organism in which unemployment, mediocrity and dependence

[6] H. S. Jennings, "The Biological Basis of Human Nature." New York: W. W. Norton and Company, Inc., 1930, 384 pp.

[7] Quoted from St. John's translation, 1838.

are perhaps on the increase and from which judgment is sapped by propaganda is *aging*. Owing to advances in medical care and to improvement in living conditions most of us last longer than our forefathers did. Life expectancy is the number of years that the average new-born babe will live. It is what insurance companies use in calculating premiums. Fairly accurate data are available on changes in life expectancy in the United States.[8]

Shortly after the Constitution was written, in 1789 to be exact, life expectancy was estimated to be 35.5 years for parts of New Hampshire and Massachusetts. In 1850 it rose to 40 (for Massachusetts) and for the United States in 1900 to 50, in 1920 to 55, while in 1930 it was a fraction over 60 years. To-day it is probably 61 or 62 years. In some other countries it is more. It may go up to about 70 years. With this change wrought by science, the character of the population has altered. In the time of Washington and Jefferson there were, as always, a few very old people, but on the average our citizens were only a little more than half as old as they will be before this generation fades away. This gradual tempering of youth, during the past 150 years, with the longer memory, experience and conservatism of older people, has undoubtedly been a wholesome factor in the development of our national habits of thought and action.

The technique of dictators is to-day, as in the past, to run away with the situation by ignoring the mature judgment of the adults and aged and by pandering only to the youth of the nation. Young people are temperamentally more visionary and inclined to idolize their leaders. Flushed by enthusiasm they are less likely to carefully think out policies and probable consequences. Theirs is a tendency to action and the devil take the hindmost. Youth movements are a very important means of progress. They have glamor, but they represent only a fraction of any population and they tend to be unbalanced. It will be freely admitted that social integration is more needed in an aging nation. There is a greater range of age, of likes and dislikes, hopes and fears to be integrated into a harmonious whole. We are permitted to believe that nature makes provision for it by increasing maturity of judgment.

There is another important point. Fairchild[9] remarks upon the leveling off of the population. "There are more than 1,600,000 fewer children under 10 now than there were five years ago." He quotes figures by Kuczynski. The figure 100 is taken to indicate a net reproduction, sufficient to maintain a population without increase or decrease. The estimates are for: England and Wales, 88; Germany, 89; France, 93.7; United States (1934), 100.

We observe, probably with some surprise, that France appears to be contracting, as far as number, less rapidly than Germany. Goebels may call for 10 million, 20 million, nay even for 30 million more Germans, but he is tilting against a whirlwind. He can retard the process of contraction just a little and very temporarily, for it is at best a long-range task; but, save by forceful annexation of additional Germans, it is safe to say that he can not materially alter this fundamental process.

Turning to the United States, Kuczynski believes that we have already embarked upon a phase of population decrease; that is to say, the figure has sunk below 100. If checked at the right time, this leveling is really a great blessing attributable to a common-sense realization of social values, though some may, at first sight, be fearful and fail to penetrate the disguise. Evidently it means

[8] Details given by L. I. Dublin and A. J. Lotka, "Length of Life—A Study of the Life Table." New York: Ronald Press, 1936.

[9] *Harper's*, May, 1938.

that we are mercifully delivered from the obligation of providing for a larger and larger population and can devote our attention to striving for quality.

Therefore in any penetrating consideration of science and social values it is necessary to be realistic and to remember that the adjustment is one of an aging population which is not expanding numerically. For several reasons we are insistently brought back to a study of the aged among us. When there are not enough jobs to go around it is the aged, the women and the children who are deprived of them first.

We know that there is a general tendency to retire elderly people from employment earlier, to make room for those in the prime of life; but accurate figures are difficult to find. However, it is reliably reported that of almost 500,000 persons on relief those between 25 and 35 were taken off the relief rolls and found reemployment in the proportion of 2 to 1 as compared with others between 35 and 45. The latter have only half a chance. How small, relatively, must be the opportunity of men and women from 45 to 55, who are not classed as old people and who are below the usual retiring age.

Another significant fact is the discovery that in the past 50 years the percentage of gainfully employed women in the United States has increased from 14.5 to 22 per cent.[10] Because the ratio between the sexes remains about the same, and the increase can not be wholly attributed to the opening up of new kinds of work, there must have been some displacement of males, especially in certain walks of life in which women are more efficient than men and work by them is a social asset. Our fathers were content with attractive male secretaries, but we are not. Who would want a male nurse? Male telephone operators are seldom in the running. Elaboration is desirable, but time does not permit. It can be said, also, that opposition from some quarters to legal restrictions on child labor is not unrelated to a hard-boiled desire to hold a larger number of jobs open for adults. In unemployment there are many factors besides labor-saving devices. Volumes are written about them.

Social adjustments to meet the impact of applied science have been woefully neglected and are just now in the making. It is no exaggeration to say that the greatest untouched problem is to find out by sustained investigation how people past maturity, who constitute such a large fraction of the population, can help us, and to profit by their efforts. To go ahead, without their cooperation, is lop-sided and short-sighted.

What, however, do we find? Men and women still vigorous and useful are forced to take a back seat. Hundreds of millions of dollars are appropriated annually to keep the unfortunate among the aged from actual want. This is really conscience money. We know that they suffer in mind and body, and to pay them a small dole is the easiest way out for us. They are all right in their place. We shrug our shoulders, thinking death is inevitable anyway and nothing can be done about it. Seldom do we trouble to explain this neglect. The aged are taboo. We turn from them to beautiful, starry-eyed children full of promise for the future. Let us not forget that those past 60 or 65 are the problem children of science, needing care and capable of making great contributions to social values.

Now for the future. Here the best of scientists become unscientific. They know it, and hence are reluctant to hazard opinions which may be dished up to them when things happen differently later. To estimate in advance the influence of any scientific discovery on our aging and slowly shrinking body politic, one must have the wisdom of a Solomon.

[10] W. E. Weld, *New York Times*, April 20, 1938.

Take the telephone. My father told me that Alexander Graham Bell offered a half share in his invention to any one at Brantford, Ontario, who would give him $100 for expenses. But the idea seemed so incredible that nobody was ready to risk this amount in such a wild-cat scheme. The worthy citizens of Boston 53 years ago thought that they acquired merit when one of their newspapers felicitated the police for arresting a criminal on the charge of "extorting funds from ignorant people by exhibiting a device which he says will convey the human voice over metallic wires."[11] It could be done elsewhere, but not in Boston!

What can be more important or thrilling than to peer into the future with the purpose of putting science to proper use? We think at once of President Hoover's Committee on Social Trends and of President Roosevelt's National Resources Committee. It is comforting to find that the work of the latter supports and extends the efforts of the former, that some members of the first committee have played a leading part in the second and that both have been constructive in the best sense of the word.

We have time to consider only a few of the conclusions reached by Roosevelt's Committee. It concerned itself with those inventions likely to exercise a profound influence on manner of life and employment within the next twenty years. The mechanical cotton picker is placed by the committee at the head of the list. The danger is fully appreciated both by the inventors and by the thinking public. Professor Ogburn is quoted[12] as follows: "Will the surplus labor of the South flood the Northern and Western cities? . . . The influence on Negroes may be catastrophic. Farm tenancy will be affected. The political system of the Southern States may be greatly altered," etc.

[11] *Reader's Digest*, August, 1937.

[12] *New York Times*, July 18, 1938.

The production of artificial cotton from plant cellulose is listed, after careful deliberation, as another possibility. This, if done cheaply, may deliver another body blow by displacing natural cotton and the mechanical picker.

The feasibility of constructing steep flight airplanes has, the committee believes, been proved. Planes which can take off and alight in the back yard will change the whole problem of transport and serve to overcome city, state and national boundaries. The frame of things will certainly become disjointed.

Think what the 25,000,000 motor cars now in use have done for us. Yet in 1900 a newspaper congratulated Theodore Roosevelt for his "characteristic courage" in venturing to ride in an automobile. And in 1908 J. P. Morgan and Company declined to pay $5,000,000 for securities which were later incorporated in General Motors and rose to $200,000,000. There are many surprises in store for us.

The greatest danger is that, in the regulation of science to extract the greatest social value and, at the same time, to prevent dislocation, human activities may be so drastically regimented that liberty and individuality will be lost. Unhappily mechanical science is impersonal; instead of emphasizing human values, it breeds a conception of the insignificance of human beings. In one dictator nation the claim is made that unemployment is solved. It is really hidden by creating socially useless work in the army, by depriving women of the position gained a generation ago and by ruthlessly displacing a racial minority.

What must we do? All this is rather a bleak picture of science and social values, but there is always the bright side. I could sing a hymn of praise to science, but that is not my present task. We obviously want science to develop, and it is our hope that it will be better adjusted to our social fabric. To say that this integration is not our job is to

pass by on the other side. It is for university people to come out of the cloister, to take a helpful interest in government and in education beyond our doors.

The first sentence of Carrel's declaration will bear repeating. He spoke about the enormous advances in the chemical and physical sciences of inanimate matter as compared with those in biological science. But the most telling pronouncement is that of Charles W. Eliot, long president of Harvard and himself a chemist: "The human race has more and greater benefits to expect from successful cultivation of the sciences, which deal with living things, than with all the other sciences put together."[13] We need to know more about life in all its aspects, for it is our lives which must be adjusted to the march of time and mechanical science.

The strategic thing is to start at the bottom and to build up. According to Dr. Riddle of the Carnegie Institution, the teaching of biology in the public schools is about 30 years behind the times and is falling off in quality and quantity.[14] The intellectual freedom of the teachers is at stake. They are hired and fired by the local school boards. Riddle states that "During the past 17 years five states (if we include Utah) have passed laws which prohibit the teaching of evolution in their public schools." Mention can be made of biologists who have been discharged, but to do so is not politic. The states are: Tennessee, Arkansas, Mississippi and Florida. In Utah the restriction is less drastic. Lest you take comfort in the belief that it is only in these states that teachers are told what they must and must not teach, allow me to quote from a declaration by the principal of one of Philadelphia's leading high schools. He is reported[15] in a Philadelphia newspaper of August 13, 1937, as saying in part:

> The old theory of evolutionists as to whether man is descended from the monkey has been over these many years. Such teaching is discredited and is not representative of science and so will not be found in our textbooks.
>
> The public schools teach biology. In this study, the difference of the species is indicated.
>
> The difficulty in teaching science often has been that it has been approached with an irreligious attitude. There is no such attitude among the public school teachers of Philadelphia.

It is hardly necessary to point out that the conception of evolution of man, not from the monkeys of to-day but from other animals long ago, is a fact. To set the human species apart as fundamentally different from all animals who also have certain hereditary endowments and must breathe, eat and drink and adapt themselves to their environments is to inhibit progress. Much of our knowledge about man is derived from close comparison of the species with other animals. Religious attitude has nothing to do with it. That is a personal matter concerning which there should be no dictation to our public school teachers. The principal has misstated the concept of organic evolution, has outlined a course of instruction which is scientifically unsound and has raised a bogey of irreligious attitude which does not exist.

Riddle believes it "unquestionable that it was traditional religion that has invoked the heavy hand of legislation" and speaks about guidance by the "dead hands of the past."

In every walk of life there are the narrow-minded, the bigoted and the fearful. But in the church to-day are many of our most socially minded and far-sighted citizens. Great is their faith in the rising generation. They welcome the fruits of scientific discovery. Not demoralization but clarification results. Surely it is fitting for these great preachers of the gospel of good tidings to take the field and use their influence to pre-

[13] Oscar Riddle, *Science*, April 29, 1938.

[14] *Ibid.*

[15] *Philadelphia Evening Bulletin*, August 13, 1937. See note 13.

vent the passage of any more such laws and to repeal those already in force. Their brothers in Germany have given a fine example of courage in fighting for freedom of teaching in the churches, while scientists, be it said to their shame, have merely bowed to authority in the universities.

The position of the 40,000 or more teachers of the life sciences is a disgrace. They, and the others, are shamefully underpaid. It is stated that 250,000 teachers in the United States were paid less than $750 each last year.[16] Laborers building motor cars are better paid than people charged with building the mentality of citizens of the United States. It is not money we lack, but perspective in social values. It will be a long time before teachers are given a chance to live decently, because they are not a pressure group and never will be. They are willing to serve the nation in this most important task of giving the rising tide of several million youngsters a true but necessarily elementary conception of life in all its main aspects. It appears to be an inexorable law that no teacher, much less a professor, gets a raise in salary beyond a pitiably small amount, unless under threat of quitting his job, and there are many ready to take his, or more often her, place.

What concretely can be done for this great group of teachers? At present they are unorganized, isolated from their fellows and find it very difficult to keep abreast of the times. The Carnegie Corporation of New York, through the Carnegie Foundation for the Advancement of Teaching, has come to a realization of their plight and has financed a study of the situation by a grant of $10,000 to the Union of American Biological Societies. The work is in charge of a committee of the union headed by Dr. Riddle and a National Association of Biology Teachers is being formed.

[16] *St. Louis Post-Dispatch*, March 26, 1938.

But the teaching of the life sciences, however excellent, is not sufficient. We must somehow get over to these children, who will take our places, an idea of ethics, of the right thing to do. This ethics must be superior to our own, for there is evidence that we have lost ground, as compared with our fathers and mothers. They were more apt to stay at home, to live their lives in smaller communities where they were well acquainted and where most misdeeds or unkindnesses affected people they knew and liked. Moreover, they were easily found out, and honesty was clearly the best policy.

Now, we hurry from place to place, meet a great many people whom we never get to know well, and for whom we do not feel the same personal responsibility. To steal from a passerby on the highway is ethically as bad as for Jones to steal from his friend Smith next door in a small village. The thief on the highway, however, has a far better chance to get away with it.

An impressive statement could be made of the increasing cost of crime. What I wish to stress, however, are the intangibles; not the anti-social but the unethical, if there is a real difference between the two. It used to be said that "a man is so mean that he does not even pay his taxes." To-day, tax evasion is a fine art. Ghost voters are frowned upon; but we all know with what complacency some of our leaders pass off as their own the work of ghost writers. And the socially elect give advertising testimonials for products which it is doubtful whether they ever use. With apparently increasing ease we protest less and less about actions we know to be wicked on the basis of "the mind your own business" policy. This anti-social attitude is considered a virtue and some are proud of it.

Years ago in England there were, as now, cases in which operation of the legal machinery did not achieve ethical ends.

The King stepped in and followed the dictates of his conscience, which was called "equity." The word is still with us; but decisions, on the basis of equity, are strictly limited. Right and fair dealing are often subordinated to legal technicalities.

We are becoming callous to human suffering as long as we do not see it before our eyes. The vicious doctrine that the end justifies the means is condoned. The savagery with which scientific discoveries are utilized to destroy social values in warfare has increased to a dreadful extent. The concept of social responsibility between peoples embodied in the Covenant of the League of Nations is repudiated. The Neutrality Act is anti-social, since in operation it gives comfort and actual help to the aggressor. The invasion of China is carried on with the aid of California oil.

The only ethical justification for neutrality is ignorance. When the facts become known in any dispute we are obliged, unless we are wholly anti-social, to form an opinion and to act to the best of our ability. To refrain from expressing this opinion; because, for selfish motives, we do not wish to be drawn into the controversy is to be unethical. Yet how often do we simply shrug our shoulders and say we haven't time? All of us can not be uplifters; but the basis of public ethics must be broadened and, in shaping it, the higher education given in our universities should supply some leaders.

Is the slump in ethics another manifestation of failure to adjust ourselves to the onrush of science? I think it is. We can speak thousands of miles and our actions are felt around the world. Our sphere of influence has, however, expanded out of all proportion to our sense of responsibility. We find it difficult to catch up with the results of what we do individually and nationally. The tragedy is that we do not care very much as long as no harm is done in our own narrow social environment. For the isolationists this environment is contracting.

Coming back to our thesis, it can be said that the proper use of scientific discovery, having in mind its social value, is our mainstay. To hold to it is very difficult, but I firmly believe that the life of each one of us will be richer if, in addition to dedicating ourselves to the advancement of science, we devote a little time to some specific social service which does not profit us directly, but which is designed to help our neighbors near and far.

MOTHER OF COMPTONS

By MILTON S. MAYER
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Honorary degrees are supposed to signify achievement. Sometimes they signify the achievement of the recipient in science or the arts. Sometimes they signify (though seldom openly) the achievement of the college in wheedling a new dormitory from a prosperous citizen. A few years ago Ohio's historic Western College for Women bestowed a doctorate of laws for neither of these reasons. The recipient, whose bearing denied that a woman is old at 74, was awarded the LL.D. "for outstanding achievement as wife and mother of Comptons."

Having received this recognition of her contribution to American life, the new doctor hurried back to the welcome obscurity of an old frame house on a quiet street in the little college town of Wooster, Ohio. Otelia Compton doesn't want to be famous, and she isn't. Four of the men to whom she is wife or mother occupy a whole page in "Who's Who in America," but the larger achievement of a middle western farm girl is unrecorded.

Those who extol the virtues of heredity may examine with profit the Compton family tree. For the ancestors of the first family of science were common farmers and unskilled mechanics, and the only one of them associated with scholarship was a carpenter who helped nail together the early buildings of Princeton. True, Elias Compton and Otelia Augspurger both taught school to help support the farms on which they were born, but so had farmers' sons and daughters before them. And there was no reason to predict that the union of two country school teachers would produce a page in "Who's Who."

Nor could the naked eye distinguish in the simple Compton household a special genius in the practice of domestic wisdom. Still, the genius must have been there, for of the four children born to Elias and Otelia Compton, Karl, the oldest, is a distinguished physicist, now president of the great scientific institution, Massachusetts Institute of Technology; Mary, the second, is principal of a missionary school in India and wife of the president of Allahabad Christian College there; Wilson, the third, is a noted economist and general manager of the U. S. Lumber Manufacturers' Association, and Arthur, the "baby," is, at forty-five, one of the immortals of science—winner of the Nobel Prize in Physics.

How did it happen? The answer of the four famous Comptons is a nod in the direction of the old frame house in Wooster. In the "sitting room" at Wooster I found Elias Compton, beloved elder statesman of Ohio education, who died last May at the age of eighty-one. He taught philosophy at Wooster College for forty-five years. But I did not find the answer to my question in the sitting room, for the father of Comptons explained that he was just one of Otelia's boys and referred me to the kitchen, where the mother of Comptons, at the age of 79, manages the home that gave America one of its most eminent families.

It is characteristic of Otelia Compton's philosophy that she should deny she has a recipe for rearing great men and women. She will admit that her children are "worthy," but what the world calls great has no significance for her. When she heard the news that

Arthur had won the world's highest award in science, her first words were. "I hope it doesn't turn his head." In the second place, she refuses to be an expert and has never before permitted herself to be quoted on the secret of successful motherhood. The only way I was able to pry her loose from her reticence was to get her into a good hot argument.

That was the weakness in her armor. For this doctor of laws actually has a set of laws, and to challenge them is to ask for a fight. There is nothing unfair about picking an intellectual quarrel with this woman of almost eighty years; she is more than equal to it. She reads as ardently as any scholar. She thinks as nimbly as any logician. And her youthfulness is such that when, one day this summer, she forgot to take off her wrist-watch before her daily swim, her children kidded her about getting old.

She may disclaim her expertness, but her record is against her. There are her four children, with their total of thirty-one college and university degrees and their memberships in thirty-nine learned societies. They didn't just grow. In addition, there are the hundreds of boys and girls whose lives Otelia Compton shaped during the thirty-five years she spent directing the Presbyterian Church's two homes for the children of its missionaries. Cornered in her kitchen, the mother of Comptons simply had to admit that she knows something about motherhood.

Her recipe is so old it is new, so orthodox it is radical, so commonplace that we have forgotten it and it startles us. "We used the Bible and common sense," she told me. I replied that "the Bible and common sense" was inadequate, since the Bible has been misused by knaves and common sense is an attribute every fool imputes to himself. She looked at me hard through her gold-rimmed glasses. Slowly her gray eyes softened. She smiled, and told me to go ahead and tell her what I wanted to know.

The first thing I wanted to know was, "How important is heredity?"

"That depends on what you mean by heredity."

"Well," I said, "let's say 'blue blood.'"

That was easy for the descendant of Alsatian farmers. "If you mean the principle that worth is handed down in the bloodstream, I don't think much of it. Lincoln's 'heredity' was nil. The dissolute kings of history and the worthless sons and daughters of some of the 'best families' in our own country are pretty good evidence that blood can run awfully thin. No, I've seen too many extraordinary men and women who were children of the common people to put much stock in heredity.

"Don't misunderstand me. There is a kind of heredity that is all-important. That is the heredity of training. A child isn't likely to learn good habits from his parents unless they learned them from their parents. Call that environment if you want to, or environmental heredity. But it is something that is handed down from generation to generation."

In connection with misplaced faith in heredity, the mother of Comptons has something to say about the notion held by so many to-day that their children "haven't got a chance." It is a notion, she feels, which is becoming entirely too prevalent. "This denial of the American reality of equal opportunity," she said, "suggests a return to the medieval psychology of a permanently degraded peasant class. Once parents have decided their children haven't got a chance, they are not likely to give them one. And the children, in turn, become imbued with this paralyzing attitude of futility."

Certainly the four young Comptons would never have had a chance had their parents regarded economic hardship as insuperable. Elias Compton was earn-

ing $1,400 a year as a professor while his wife was rearing four children and maintaining the status a college community demands of faculty households. The children all had their chores, but household duties—and here is an ingredient of the Compton recipe—were never allowed to interfere either with school work or the recreation that develops healthy bodies and sportsmanship.

If heredity is not the answer, I wanted to know, what is?

"The home."

"That's a pleasant platitude," I said, in an effort to draw my "opponent" into the middle of the ring. I succeeded.

"It's a forgotten platitude," she replied sharply. "The tragedy of American life is that the home is becoming incidental at a time when it is needed as never before. Parents forget that neither school nor the world can reform the finished product of a bad home. They forget that their children are their first responsibility.

"To-day servants are hired to take care of children. In my day, no matter how many servants a mother could afford she took care of her children herself.

"The first thing parents must remember is that their children are not likely to be any better than they are themselves. Mothers and fathers who wrangle and dissipate need not be surprised if their observant young ones take after them. The next thing is that parents must obtain the confidence of their children in all things if they do not want to make strangers of them and have them go to the boy on the street corner for advice. Number three is that parents must explain to the child every action that affects him, even at the early age when parents believe, usually mistakenly, that the child is incapable of understanding. Only thus will the child mature with the sense that justice has been done him and the impulse to be just himself.

"The mother or father who laughs at a youngster's 'foolish' ideas forgets that those ideas are not foolish to the child. When Arthur was 10 years old he wrote an essay taking issue with other experts on why some elephants were three-toed and others five-toed. He brought it to me to read, and I had a hard time keeping from laughing. But I knew how seriously he took his ideas, so I sat down and worked on them with him."

Arthur—he of the Nobel Prize—was listening to our conversation, and here he interrupted. "Mother," he said, "if you had laughed at me that day, I think you would have killed my interest in research."

"The reason why many parents laugh at their children," Mrs. Compton went on, "is that they have no interest in the child's affairs. The mother and father can not retain their influence over their children if their children's life is foreign to them. And it isn't enough to encourage the child; the parents must *participate* in his interests. They must work *with* him, and if his interest turns out to be something about which they know nothing it is their business to educate themselves. If they don't, the child will discover their ignorance and lose his respect for them."

When Karl Compton was twelve, he wrote a "book" on Indian fighting. Mary was absorbed with linguistics. Wilson's devotion to the spitball made him the greatest college pitcher in the Middle West. Arthur, too, was a notable athlete, but his first love was astronomy. The combination of Indian fighting, linguistics, the spitball and astronomy might have driven a lesser woman to despair, but Otelia Compton mastered them all as she did their other diversions. For instance, the summer the Compton family caught 1,120 pounds of fish, mother landed her share.

All the toys the young Comptons had could have been bought for a few dollars, but when the four of them were still

under ten years of age their mother packed them up, together with a father who had almost died from pneumonia, and took them to the wilds of northern Michigan, where mother and children hewed a clearing and pitched a tent. There these urban-bred children learned simplicity and hard work. There they found that the things which tempt children need not be forbidden them when those things are fishing and woodcraft and the stars. There they imbibed, as the mother of Comptons would have every city child imbibe, of the unity and mystery of nature.

The boys all worked summers and in college, gaining priceless experience; and they all had their own bank accounts, "not," their mother explains, "because we wanted them to glorify money but because we wanted them to learn that money, however much or however little, should never be wasted." Would she put hard work first in her lexicon? Mrs. Compton thought a moment. "Yes," she said, "I would. That is, hard work in the right direction. The child who has acquired the habits of work of the right kind does not need anything else."

And what is the "right kind" of hard work?

"The kind of work that is good in itself."

I baited the trap. "What's wrong with working for money?"

The mother of Comptons exploded. "Everything! To teach a child that money-making for the sake of money is worthy is to teach him that the only thing worth while is what the world calls success. That kind of success has nothing to do either with usefulness or happiness. Parents teach it and the schools teach it, and the result is an age that thinks that money means happiness. The man who lives for money never gets enough, and he thinks that that is why he isn't happy. The real reason is that he has had the wrong goal of life set before him."

What did she mean by parents and schools "teaching" that money is happiness?

"I mean all this talk about 'careers' and 'practical' training. Children should be taught how to think, and thinking isn't always practical. Children should be encouraged to develop their natural bents and not forced to choose a 'career.' When our children were still in high school, a friend of ours asked Elias what they were going to be. His answer was, 'I haven't asked them.' Some of our neighbors thought we were silly when we bought Arthur a little telescope and let him sit up all night studying the stars. It wasn't 'practical.'"

Yet it was his "impractical" love of the stars that brought him the Nobel Prize and something over \$20,000; and in order that he might pursue his cosmic ray research, the University of Chicago equipped a \$100,000 laboratory for him.

I thought of the four Comptons and the success that has resulted from their early training, and I wondered if "impractical" parents weren't perhaps the most practical. What could be more tangible than the satisfaction and the honors that have come to them because of their far-flung labors?

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

CHEMISTRY AND PHYSICS IN AID OF HEALTH

ONE of the brightest spots on the picture of to-morrow's health is being painted in to-day by chemists and physicists working with physicians and other medical scientists.

The x-ray was an early important contribution of physics to the healing art and science. The tagged atom of artificially radioactive material, made in the atom-smashing cyclotron, is the latest such contribution. X-rays enable physicians to see inside the body, to see broken bones, ulcers and even cancers of internal structures. Tagged atoms are helping scientists to trace the distribution of various chemicals in the body tissues and to learn more of how they are utilized.

On the chemical side, advances lately have also been very rapid. Sulfanilamide was for a long time just a waste product in the dye industry. Then suddenly, under the guise of Prontosil, it burst upon the medical world as a remedy for childbed fever. That was only yesterday. To-day sulfanilamide is on every one's tongue because it has become an effective weapon against erysipelas, scarlet fever, meningitis, gonorrhea, streptococcus throat infections and even pneumonia. In addition, sulfanilamide has started a fresh wave of search for chemical remedies for many ailments.

It is not only by the discovery of new remedies that chemists are helping physicians to improve the health picture. Speaking on this point, Dr. Stuart Mudd, of the University of Pennsylvania, recently said: "A striking aspect of recent medical progress is that both normal physiological processes and the abnormal process of disease are finding explanation in terms of the chemical substances responsible for them."

WORLD INQUIRY INTO SOCIAL EFFECTS OF MODERN SCIENCE

A WORLD inquiry into the part that science plays in modern society is under way and will come to fruition, the international situation willing, probably in 1940. It is the work of the Committee on Science and its Social Relations (C.S.S.R.) instituted by that closest approach to a world super-government for science, the International Council of Scientific Unions, in May, 1937.

Using elaborate questionnaires as a mechanism, a fact-finding campaign is being conducted through the agencies of nationally representative scientific organizations of the various countries. In America, this would be the National Academy of Sciences; in Britain, it would be the Royal Society of London.

There will also be special inquiries along specialized lines, with questionnaires for mathematics, astronomy, mechanics, physics, chemistry, biology, geophysical sciences, geography. Because some fields are not represented by the unions that compose the International Council, the medical and engineering sciences, agriculture, sociology and economics are not being included in the first inquiries.

The organization of the international inquiry is in the hands of Professor J. M. Burgers, of Delft, Holland, secretary of the C.S.S.R. In addition to the official questioning and compiling contemplated,

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

there is a place in the plans for assistance from individual scientific investigators. Such points as these, it is felt, might be answered more effectively by individual than by official organizations:

(1) The part played by scientific thought in the outlook of various social groups.

(2) The forms in which scientific workers and their work are involved in the various struggles and conflicts of human society.

(3) The forms in which the consciousness of a social responsibility of science and of scientific workers is taking shape.

These are matters of extreme importance in the large vistas of the world. If they seem less important than fast-marching current affairs, it is largely a matter of perspective. The fear is that the forces of violence will throttle the opportunity of such deliberate assaying of the science that has made civilization.

NEW COSMIC RAY PARTICLE

THE physicists have nearly as much trouble naming a new fundamental particle as a family of fond parents, grandparents and in-laws deciding what to call a new baby.

Now it is the heavy electron, the particle that lives only about a millionth of a second after being born of the cosmic rays, that is being christened enthusiastically.

Americans are calling the heavy electron "baryton," the first part of the word being Greek for "heavy." But Europeans, with Professor Niels Bohr, of Copenhagen, as chief protagonist, are using "yukon" in honor of the Japanese physicist, Yukawa, who postulated the existence of the particle before Drs. C. D. Anderson and Seth Neddermeyer, of Pasadena, discovered it in 1937.

In discussion at the recent Cambridge meeting of the British Association, one of the Americans present observed that yukon was a rather cold name for a particle so hotly discussed and that Alaskans might protest.

The heavy electrons seem to make up the major portion of the penetrating particles resulting from the cosmic radiation. Scientists are flying high into the atmosphere and setting up apparatus deep in tunnels in order to study them.

With some 240 times the mass of the ordinary electron, basic unit of electricity, the heavy electron is lighter than the proton, the nucleus of the hydrogen atom. It may very well be triplets, for it would be logical for it to be found with negative and positive charges as well as no charge at all.

It is a very unstable creature, existing theoretically for a mere millionth of a second when at rest. Strangely enough, it lives longer when it goes fast, owing to the relativistic change in time. One of them by great good luck was photographed at Pasadena coming to rest. Heavy electrons are supposed to disintegrate into electrons and neutrinos. And neutrinos are particles postulated but not yet discovered.

SOAP BUBBLES AND EXPLOSION STUDIES

AT the National Bureau of Standards in Washington Uncle Sam's scientists have been blowing bubbles in the laboratory and learning new secrets of how explosions occur in gases. Particularly they have been seeking to learn how fast a flame from an explosion will speed through space, a matter intimately tied up with explosive fires and indirectly with the efficiency of internal combustion engines.

Scientists Ernest F. Fiock and Carl H. Roeder, in a report prepared for the National Advisory Committee for Aeronautics, outline their methods of soap-bubble blowing and why it has value in combustion and explosive research projects.

The trick is to blow a soap bubble

with an explosive gas, such as carbon monoxide, and make it form around a gap between two metal wires. Across this gap an electric spark can be made to jump, ignite the gas and create the explosion. Just as the explosion is to occur a high speed motion picture camera, taking over 1,600 frames a second, goes into operation and photographs the progress of the flame.

Key point of the soap bubble method is that it occurs essentially in free or unconfined space, because the soap film expands very easily to any pressure increase. As a matter of fact, the method is said to give results under constant pressure and at the same time enables the direct observation of the relative speeds of the flame and the expanding, but yet unburned, gases.

For explosions of carbon monoxide it was found that flame speeds reached values of 900 centimeters per second or about 20 miles an hour.

The soap bubble method has been a pioneering effort in the broad study of gaseous explosions. The general project is being continued, says Mr. Fiock, by additional methods which should have an even wider range of applications.

MALNUTRITION AMID FOOD PLENTY

THERE are thousands of Americans who live in a land of food plenty and yet suffer from hunger. This is not a story about economics and how badly we distribute our agricultural products. It is a story of hidden hunger, the diseases of malnutrition. It is an ABC story because it is about vitamins.

The best estimates or guesses as to the prevalence of nutrition diseases can not be backed up by figures because, except for pellagra in some southern states, the deficiency diseases are not reportable. Yet people die of them.

The prize medical story in this regard comes from one of the largest of New England cities. A woman was found dead at the bottom of a staircase in a not-too-well-off residence. She was covered with what appeared to be livid bruises. Naturally the husband was taken into custody by the police. He might have been tried for murder, except that a keen-eyed coroner-physician, performing the autopsy, rendered a verdict that set him free. The woman had died of acute scurvy, the symptoms of which made her appear to have been badly beaten. Scurvy is caused by a lack of vitamin C contained typically in citrus fruits.

Lack of vitamin A causes a form of night blindness, sometimes involved in auto accidents. This vitamin is contained in butter. When during the world war, no butter was available and skim milk was used widely in some Scandinavian areas because butter could be sold at such high prices, eyes of some children were permanently injured.

Rickets is widely found in rich and poor children alike, despite all the cod-liver oil and vitamin D extracts sold and administered.

All the pellagrins, those who do not get the P-P factor that prevents pellagra, are not in the southern states. It is found in northern areas and large cities where lack of money, alcoholism or idiosyncrasies of diet prevent eating proper protective food.

Beri-beri is occasionally found in America. Its cause, which is lack of vitamin B one, is also blamed for neuritis frequently associated with other diseases in this country.

CORROSION WASTES

THE war-basis budgets of the nations of the world reach staggeringly large figures, but the most costly single item which the United States or any other nation faces is the cost of corrosion and its prevention.

This is the estimate of C. E Heussner,

materials engineer of the Chrysler Corporation, who computes the world cost of the corrosion damage of metals alone at some $5,000,000,000 each year.

Each year a quarter of all the iron in the world returns to oxides or ores from which it came, Mr. Heussner states in an American Society for Testing Materials summary.

Much of the iron thus corroded is lost permanently, for while it is theoretically possible to send the iron oxide back to a plant and convert it into commercially pure iron again, the iron rust is so scattered that it is economically useless to collect it and start over again. It is only economical to try and collect the unrusted parts of scrap metals. Hence the place of the junkman in modern society.

Speaking rather loosely, we talk of rust-proof metals and corrosion-resistant materials, but in actual fact all metals and protecting surfaces fall down in special cases and what is good for one job is useless in another. Everything depends on a metal's environment, the conditions under which it will be used in service.

Ordinary steel, as one example, needs plenty of protection. It rusts in moist air and dilute nitric acid. But if steel is immersed in concentrated nitric acid—a potent solvent—it will not dissolve. The steel becomes passive and acts like a noble metal. In this environment steel *is* a noble metal, H. W. Gillett, of the Ohio State University's Battelle Memorial Institute, observes in another part of the report on corrosion.

FORESTS FOR AMERICA'S FUTURE NEEDS

During the past ten years a quiet revolution has taken place in this country. It has little or nothing to do with the socio-political field—there has been a revolution there, too, if you like; but nobody could claim it was a quiet one.

Our quiet revolution, nevertheless, affects the lives of all of us and will continue to do so for a long time to come, for it is in the field of forestry. Ten years ago Congress enacted the McSweeney-McNary bill, which placed forestry research in this country on a solid, systematic basis. This month, foresters are celebrating the decennial of their Magna Charta, and a special issue of the *Journal of Forestry* is devoted to a discussion of scientific progress in all branches of forestry during that period.

There is a lot more to forestry than just going out and planting a lot of new trees where old ones have been cut down. Managing a forest is a more complex job than managing a factory—or even a whole chain of factories, for forest products cover a range all the way from timbers and turpentine to such intangible services as watershed protection and fun for fishermen. And forest research must take all these things into account.

Basic idea of the research program is stressed by Dr. Earle H. Clapp, associate chief of the U. S. Forest Service:

> The Act and the various things that have grown out of it have helped drive home the concept that the forest of any area is a biological entity, all the elements of which are integrated with all the others and are influenced by them,
>
> The biological elements of the forest of an area or region extend in the same way into the social and economical field. All of this exceedingly complex interrelationship has emphasized the need for conducting research on the basis of these relationships, or in brief, the need for cooperation by groups of specialists in coordinated, well-rounded-out many-sided attacks in contrast with isolated and purely individual work.

THE RICHMODIS LEGEND OF THE PLAGUE

By Dr. IVAN C. HALL

UNIVERSITY OF COLORADO SCHOOL OF MEDICINE AND HOSPITALS, DENVER

The gray air balanced the tone of the bell on Apostle's Church as it, like every other church bell in Cologne, sounded the hour.

The city was ravaged by plague and the terrified people, bending their backs as if under a scourge, cursed the year 1357, for they were dying like flies in autumn. In vain, the priests preached resignation; the sanctuaries were empty and people went about as if they were all afflicted with the fatal germ, while the grave diggers shoveled day and night.

One morning the toll of the bell on Apostle's Church was prolonged. At Neumarkt Platz fearful faces peered from half-opened doors; the news flew from mouth to mouth, from porch to porch. "The one who is dead, who has been carried away this very hour, is no other than Frau Richmodis. What a pity, with all the accumulated grief and sorrow! The rich, the beautiful, the good, young, lovable Frau Richmodis! The horrible plague makes no distinction!"

"It is no brilliant cortege with long procession to dignify a lady which suddenly leaves the house of death, but four black men, who carry a long box. They hasten rapidly from the place. Do they not fear the dead, who may give them death, the horrible death?"

Herr Richmodis followed them to the grave, saw his lovely Frau sink into it, and heard the first clods of earth as they fell on the coffin. He also heard the loud sobbing of the poor people whom Frau Richmodis had helped so much. Then he returned to his beautiful home, now empty and lonely.

The two grave diggers paused to rest when the people had gone. Said one to the other, "Isn't it a sin and a shame that so costly a ring with its sparkling diamond and all that gold should remain buried in the ground?" And so they returned that night, and opened the grave, to steal the valuable trinkets. But when they removed the lid of the coffin Frau Richmodis awoke with a deep sigh and slowly sat up, whereupon the grave diggers dropped their lantern and fled into the dark night for their very lives.

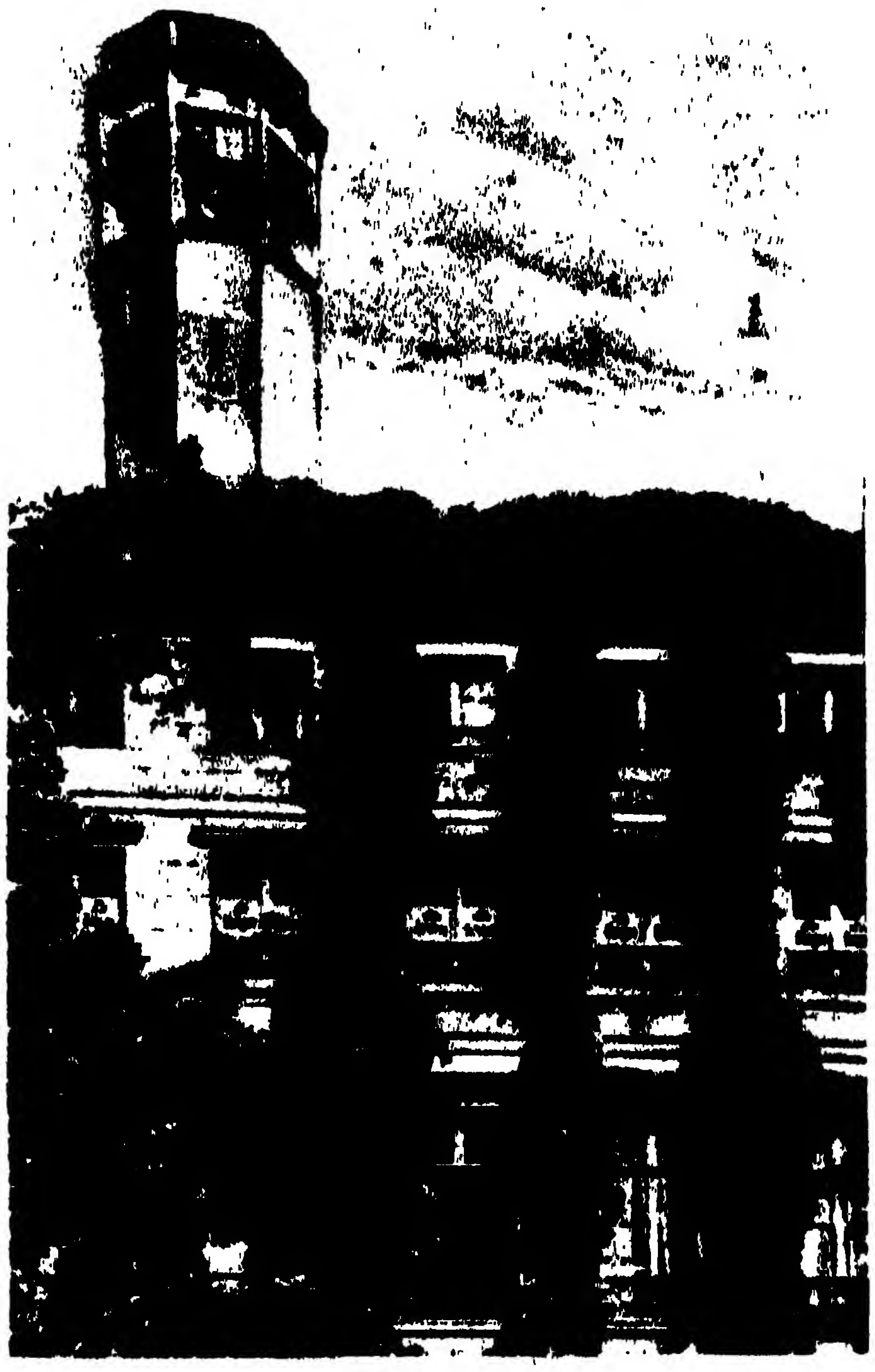


FIG. 1. THE OLD RICHMODISHAUS IN FRONT OF APOSTLE'S CHURCH IN COLOGNE, SHOWING THE HORSES' HEADS. THIS BUILDING WAS TORN DOWN IN 1927 TO MAKE WAY FOR A MODERN OFFICE BUILDING.

Pale and weak in her white shroud, Frau Richmodis found her way with the aid of the lantern along the death-still street to her own house. She rang the bell until finally a servant maid opened a window and recognized her mistress. Horrified, she slammed the window shut and was barely able to tell her master that his Frau was at the door. Said he, "It is not possible! I would as soon believe that my two horses would leave their stalls to go up the stairs and stick their heads out of the second story window." Hardly were these words spoken before the trampling of horses' hoofs was heard on the stairway. Herr Richmodis ran as quickly as he could, and, sure enough, there was his good Frau before the door. In a few days, with rest and food, she was as fresh and rosy as before. She lived a long time and had a large family.

Such is the Richmodis legend of the plague. For many years this legend was perpetuated by two carved horses' heads peering from the top story window of the vine-covered Richmodis house, which is here illustrated before the bell tower of the Apostle's Church (Fig. 1). This famous old house was demolished in 1927 to make way for a modern office building, but the tourist still sees the horses' heads high up on the face of it and hears the story from the sightseeing bus in Cologne (Fig. 2).

I am indebted to Herr D. E. Alsberg, of Richmodishaus, for the illustration, for a loaned copy of "Richmodis von Aducht" by M. Kaster, illustrated by Erika Freund, as well as a clipping from *L'Eclaireur du Soir*, December 10, 1931, from both of which the above was freely translated.

FIG. 2. THE NEW RICHMODISHAUS ON NEUMARKT PLAZA, AN ARROW SHOWING THE POSITION OF THE HORSES' HEADS.

THE PROGRESS OF SCIENCE

THE SCIENTIFIC MONTHLY AND THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

At the April, 1925, meeting of the executive committee of the council of the American Association for the Advancement of Science, the editor and owner of *Science* offered under certain conditions to let the journal, which since 1900 had been the official organ of the association, become its absolute property. The plan was approved by the executive committee, which unanimously voted "its sincere and hearty thanks to Dr. Cattell for his most generous offer." The agreement was put in contractual form by Dr. Roscoe Pound, dean of the Harvard Law School, one of the distinguished fellows of the association, originally elected for his contributions to botany. The contract was executed by the owner of *Science* and Dr. Pupin, president of the association, and attested by Dr. Livingston, permanent secretary, on July 28, 1925. It was approved by a unanimous vote of the council of the association on December 30, and a committee, consisting of Drs. Pupin, Kellogg and Livingston, was appointed to express to Dr. Cattell the appreciative thanks of the association.

At the annual meeting of the association held in Atlantic City in December, 1936, a similar offer was made in regard to THE SCIENTIFIC MONTHLY, which has been an official journal of the association since 1907 to the extent that it may be received by members in place of *Science*. The offer was referred to a subcommittee consisting of Professor Edwin G. Conklin, president of the association; Professor George D. Birkhoff, president-elect; and Professor Burton E. Livingston, formerly permanent secretary. This committee reported to the executive committee meeting in New York in April, 1937, as follows:

> The subcommittee is unanimously agreed that Dr. Cattell's proposal is a very generous one and that it will be of much present value to the association and may in the future become of still greater value. We, therefore, recommend that it be adopted with hearty thanks and that the President and Permanent Secretary of the Association be authorized and directed to take such steps as may be necessary therefor and to enter into and to execute a contract for this transfer of THE SCIENTIFIC MONTHLY from its present owner to the American Association for the Advancement of Science, in conformity with the terms of the proposal of Dr. Cattell dated December 25, 1936, and that this action be reported to the council at the Denver meeting. We also wish to express to Dr. and Mrs. Cattell our sincere appreciation of their great and long-continued services to scientific organization, cooperation and progress.

This report was unanimously approved by the executive committee and was reported to the council at the Denver meeting. In view of this action it was decided last spring to let THE SCIENTIFIC MONTHLY be edited at the Washington office of the association, and Dr. F. R. Moulton, permanent secretary of the association, and the late Dr. Earl B. McKinley, member of the executive committee, agreed to join in the editorship, Ware Cattell remaining as associate editor. Manuscripts and other editorial communications should now be sent to The Editors of THE SCIENTIFIC MONTHLY, Smithsonian Institution Building, Washington, D. C.

THE SCIENTIFIC MONTHLY, then named *The Popular Science Monthly*, was established by J. W. Youmans and the firm of D. Appleton and Company in 1872. In its earlier years organic evolution and natural selection excited controversy and wide public interest; the journal attained much influence and a relatively large circulation. The Appletons published in the United States the works of many British men of science and were able to print in the *Monthly* articles by Darwin, Spencer, Huxley, Tyndall and other lead-

ers. After the death of the elder Youmans and the development of more technical work in science the journal became unprofitable, having been conducted for a time at an annual loss of about $10,000. It was then sold to the present owner and editor.

The transfer of the journal to the American Association, combined with efficient editorship, should give the country a better journal of general science than it has ever before had. It should greatly increase the membership of the association and have the cooperation of all workers in science. There will be no change in editorial policy, but an endeavor will be made to make the journal not only authoritative, as it has always been, but of greater interest to those educated people who wish to follow the advances and share the spirit of science, the dominant factors in modern civilization.

The undertaking will be much more difficult without McKinley, who was admirably fitted for the editorship of a journal such as THE SCIENTIFIC MONTHLY. His loss with the ill-fated Hawaii Clipper, while collecting germs in the upper air for his studies on the distribution of disease, was a disaster to science the magnitude of which can only be appreciated by those who have worked with him. He was dean of the Medical School of the George Washington University and was engaged in scientific work of originality and importance. In addition to these engagements he devoted a considerable part of his time and unlimited energy to scientific organization. In recent years he has taken a leading part in the work of the American Association for the Advancement of Science and for it his loss is irreparable. As one of the editors of THE SCIENTIFIC MONTHLY he would surely have had the usefulness and the success that attended all his enterprises. McKinley had genius for scientific research, organization and administration; most of all, for friendship. There is none like him, none, nor will be.

J. McK. C.

THE RETIRING PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

AFTER a period of service of eighteen years as president of the Carnegie Institution of Washington, Dr. John Campbell Merriam will retire on December 31 of this year in order to devote his time to research in science and to writing. A research scientist, who is required to give most of his time to administrative tasks and thereby compelled to subordinate or neglect his own research activities, looks forward to the opportunity of again undertaking them in quiet and released from executive responsibilities. Provision has been made by the trustees of the Carnegie Institution to permit Dr. Merriam to do this, and he will naturally welcome freedom from the duties that rest upon the president of a large organization.

Under Dr. Merriam's leadership the Carnegie Institution has continued to grow steadily and to make many important contributions to knowledge in different branches of science. When he became its president on January 1, 1921, the institution had already established itself as an effective research agency. Founded in 1902 by Andrew Carnegie "to encourage, in the broadest and most liberal manner, investigation, research and discovery, and the application of knowledge to the improvement of mankind," the institution first sought information on problems of fundamental importance in various branches of science that could best be attacked through the cooperative efforts of groups of investigators trained in different fields. These

DR. JOHN CAMPBELL MERRIAM

problems were studied by special committees who made recommendations that led gradually to the establishment of departments of research within the institution.

The effort was also made, at the request of Mr. Carnegie, to find and to aid unusually talented men in their work. Many small grants were thus made to men over the country who had specific problems to solve. Dr. Woodward, during the early years of his presidency, examined carefully into these scattered grants and found that a surprisingly small number yielded results commensurate with the outlay. On the basis of this experience the institution gradually adopted the policy of devoting most of its available funds to support of work by its own investigators on a few large projects. A limited number of research associates of proved ability who were able to give their entire time to research work were also maintained as members of the institution; but the granting of small sums to aid in the solution of specific problems unrelated to the work of the institution was not encouraged. The institution has sought always to do scientific work of the highest quality, chiefly in experimental fields in which conclusions can be tested by laboratory experiment or by observations in the field. This method of approach is slow, but it is thorough and effective and enabled the institution to avoid many difficulties incident to early stages of development.

When Dr. Merriam succeeded Dr. Woodward as president there were eleven departments of research in the institution. They were scattered over the country and operated quite independently. This state of almost complete autonomy arose because in the early days the energies of each department were concentrated on the tasks at hand and opportunities for cooperation with other departments or with outside organizations were not emphasized; once established, this tendency toward isolation remained until Dr. Merriam sought gradually to remedy it by taking advantage of opportunities for research work requiring attack by several departmental groups or between a research group within the institution and an outside group. He visualized the institution as a unified organization devoted to the conduct of research in science and to its application to human needs.

Throughout his administration Dr. Merriam has stressed the unity of the Carnegie Institution operating through departmental groups and research associates on certain fundamental problems. This shift of emphasis from the departments to the institution itself has proved fruitful because it has provided for flexibility of planning and of coordinating attack on scientific problems to take advantage of conditions as they arose and to approach them with greater understanding. It has made possible more effective cooperation with outside agencies with resulting stimulus to creative work. It has resulted in the administrative grouping of certain departments into divisions, such as the divisions of animal biology, of plant biology and of historical research; also in the appointment of interdepartmental committees to work on special problems.

Dr. Merriam further realized the responsibility that rests upon the institution to inform the public regarding the results of its scientific activities and to interpret these results in such manner that their significance in relation to human progress may be generally understood. To meet this responsibility different steps have been taken. A public exhibition of the results obtained in certain current investigations by the institution is held each year; at this exhibition men from the departments demonstrate special phases of the work. Lectures by staff members are given in conjunction with the exhibits and at other

times during the year on special problems under investigation. Many of these lectures are published and reach a large group of readers.

The scientific publications of the institution contain part of the record of its scientific work. But these records are not read by the general public because they are too technical in form. Accordingly, under Dr. Merriam's guidance, the editor of the institution, in cooperation with staff members, has prepared for many years past accurate, readable statements on the results of work by the institution for distribution to newspapers and magazines, to staff members and to a large number of high schools. In these statements and releases serious effort is made so to present the information that the general reader will find it interesting. The problem of public relations is not easy, but Dr. Merriam's solution of it for the institution has been successful and has recently led the trustees to vote funds for the erection of an addition to the Administration Building in Washington to provide for a better lecture hall (to be called the Elihu Root Hall) and for adequate exhibition halls as well as offices and storage space. The building will be ready for occupancy before the end of this year.

Dr. Merriam has encouraged cooperative work between the institution and other organizations, especially when the combined effort has promised a better and more effective solution of the specific problems under discussion. On occasion the institution has served as an initiating and supervising agent, although the ultimate conduct of investigations thus undertaken may be under other auspices.

On retiring from responsibility for the conduct of work on these and many other problems, Dr. Merriam will carry with him the good wishes of all staff members of the institution; they have learned to look to him for advice and help and to rely upon his wise judgment in meeting situations. They realize that, in retiring, Dr. Merriam will have opportunity for important work in his own field of vertebrate paleontology and for further philosophical analysis of the meaning of science to mankind; but they will miss his constructive suggestions and his genial personality.

F. E. Wright
Geophysical Laboratory,
Carnegie Institution of Washington

THE UNIVERSITY OF NORTH CAROLINA

Assembling in Chapel Hill, N. C., for its fall meeting (October 23 to 26), the National Academy of Sciences not only makes its "farthermost south," but also becomes the guest of an "oldest state university." There are perhaps a half dozen "oldest state universities,"[1] but the University of North Carolina at Chapel Hill seems clearly to have been first to receive faculty and students, at least among those which have had any sort of continued existence as state institutions from their beginnings to the present time. Only the exigencies of war and reconstruction brought about a temporary closure from 1870 to 1875.

Authorized in the Constitution of 1776 and chartered in 1789 (not as early as some others of the "oldest"), the university began actual teaching in 1795 in a building whose cornerstone had been laid two years earlier. After a period of guidance by "presiding professors," the first president was elected in 1804. It is of interest that the terms of two presidents, Caldwell (1804–12 and 1816–35) and Swain (1835–68), spanned the entire period from 1804 almost to the closure in

[1] Dean Robert B. House, of the University of North Carolina, has already proposed the formation of a "National Society of Oldest State Universities," to comprise those institutions which severally claim to be the oldest!

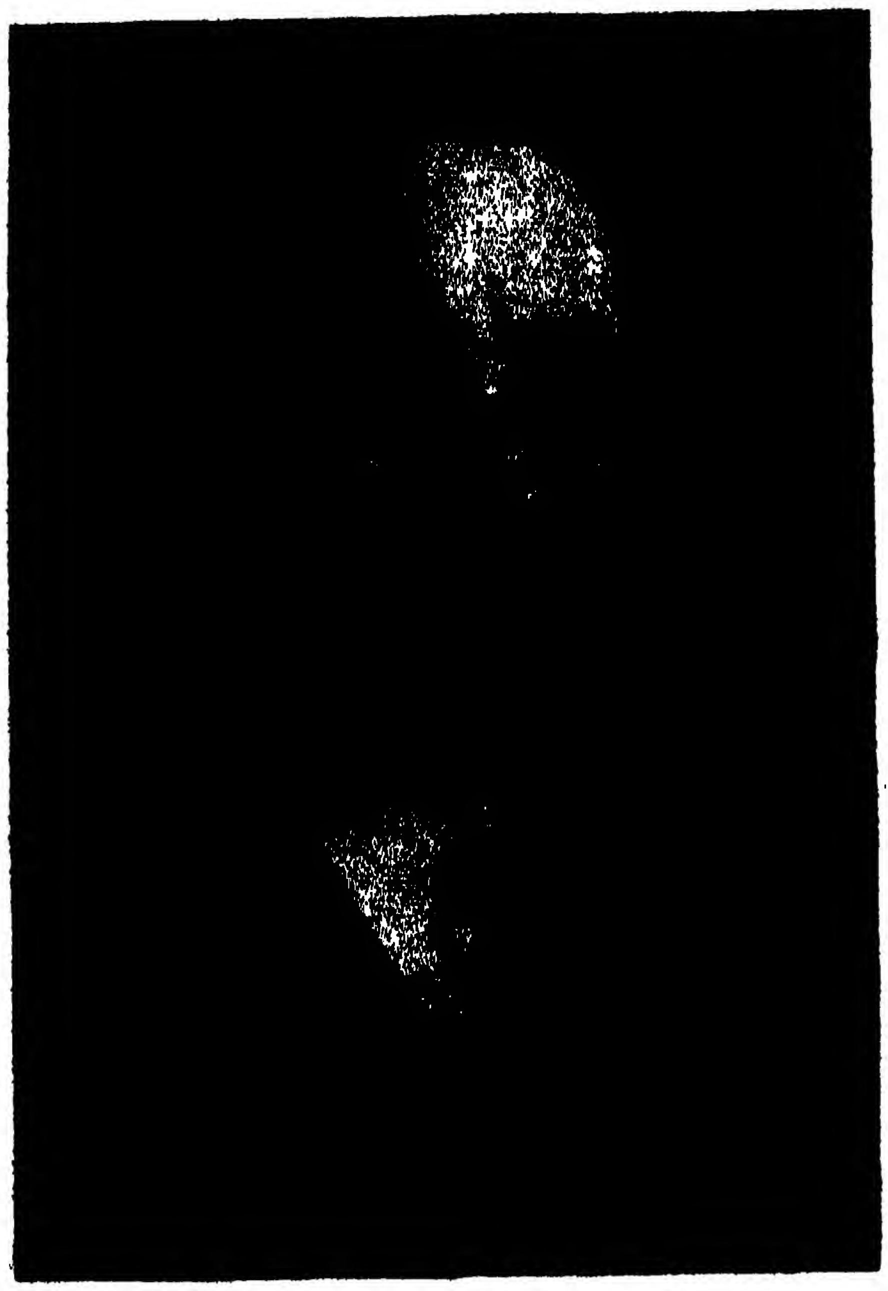
VENABLE HALL, UNIVERSITY OF NORTH CAROLINA
THE BUILDING IN WHICH THE SCIENTIFIC SESSIONS OF THE ACADEMY WILL BE HELD. NAMED IN HONOR OF FRANCIS PRESTON VENABLE, PROFESSOR OF CHEMISTRY FROM 1880–1900 AND 1914–1930, AND PRESIDENT OF THE UNIVERSITY FROM 1900 TO 1914.

1870, except for a period of four years, during which President Caldwell voluntarily found escape from the honors and responsibilities of a college presidency.

Like many other universities and colleges, the University of North Carolina had exceedingly limited financial resources during most of the nineteenth century. Nevertheless, the continuing good fortune of the university in the choice of presidents and faculty created an atmosphere of devotion to scholarship. The development of its scientific departments in recent times owes much to the vision, energies and capacities of such men as Francis P. Venable, long professor of chemistry and for a time president of the university; Joseph A. Holmes, professor of natural history, later state geologist and then organizer and first director of the U. S. Bureau of Mines; H. V. Wilson, head of the department of zoology for 44 years and now actively engaged in teaching as Kenan professor of zoology; and Collier Cobb, lately head of the department of geology.

Although the university seems at all times to have occupied a high place in the esteem of the citizenship of North Carolina, it has been only since about 1920 that the state has found itself in a position to make substantial appropriations for its support. The presidencies of E. K. Graham, Harry Woodburn Chase and Frank Porter Graham have covered the period of greatest physical expansion in buildings and equipment, in scope of instruction, in faculty and in number of students. Perhaps most prominent among the university buildings of recent construction are the library, the laboratory of chemistry (Venable Hall, where the scientific sessions of the academy will be held), Hill Hall (the home of the music department), the law building, Graham Memorial (the student activity center) and a thoroughly modern gymnasium (the Charles T. Woollen Gymnasium), which contains one of the largest indoor college swimming pools. At the present time, a large building is in process of construction to house the two-year medical school and the division of public health. Construction is about to begin also upon a laboratory of zoology, a dining hall and a number of dormitories for men and women. The renovation of several older buildings has been authorized.

In the minds of alumni, faculty and



DR. WILLIAM DE BERNIERE MACNIDER
DEAN OF THE MEDICAL SCHOOL, UNIVERSITY OF NORTH CAROLINA, MEMBER OF THE ACADEMY.

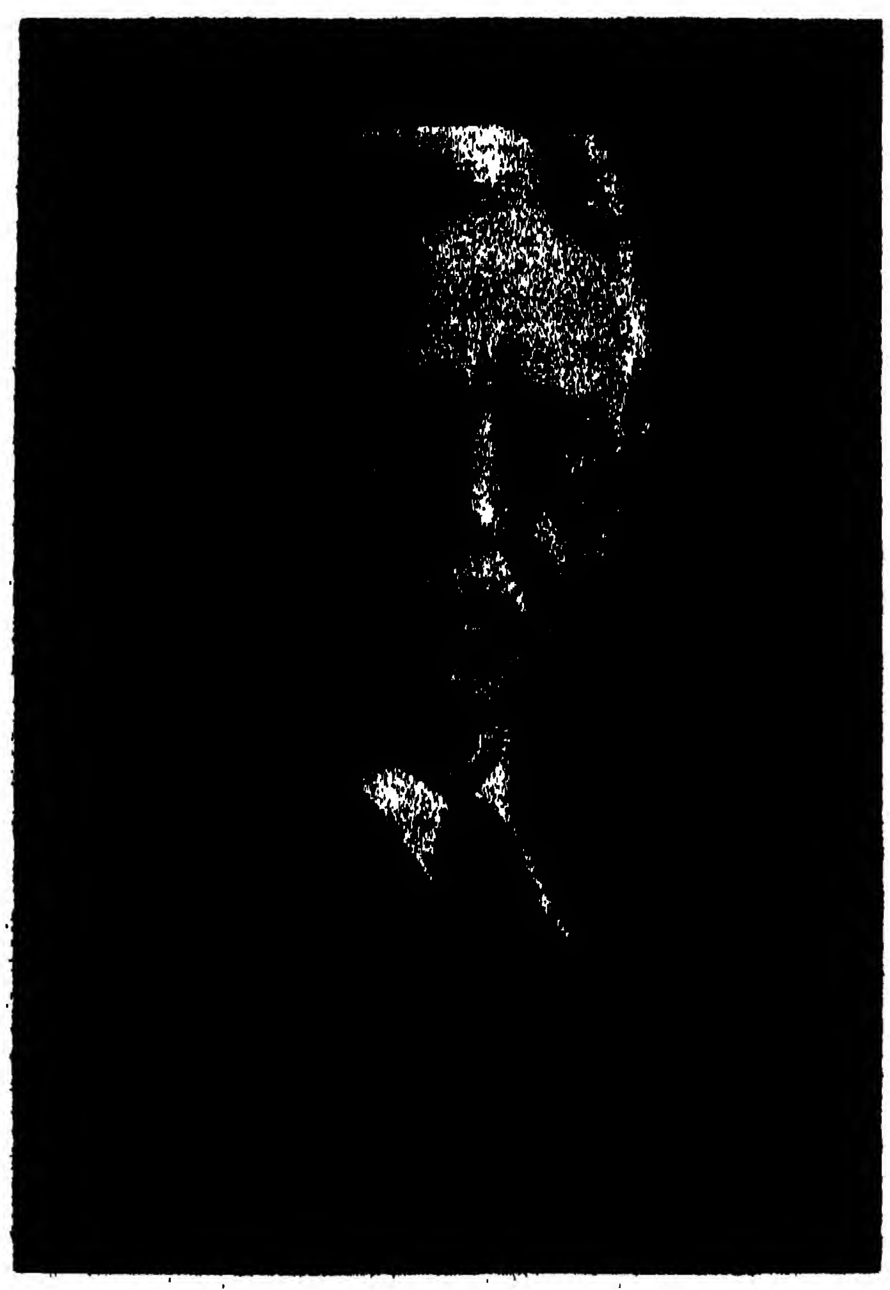
students, the new buildings are no more prominent than the old, including, first of all, Old East, the cornerstone of which was laid in 1793, making it the oldest state university building in the country. The South Building, begun in 1798 but first occupied in 1814, after being financed in part by the proceeds from a state lottery, is now the Administration Building. Of the dissimilar twins that arrived in 1822, Old West was completely renovated a few years ago, and Gerrard Hall, the old chapel, awaits an early and assured rejuvenation. Smith Hall (1852), once the library, now the Playmakers Theatre, although not among the oldest, may command the visitor's attention not so much because it is one of "the first state-supported theaters," but rather for a certain peculiarity of its architecture. On its pseudo-Corinthian columns and in accord with a suggestion of Thomas Jefferson, the classical palm-leaf motif was replaced by a more fitting American design of maize—ears, shuck and leaf with pleasing effect.[2]

Other branches of the university, as recently consolidated, are the College of Agriculture and Engineering in Raleigh and the North Carolina College for Women in Greensboro.

The country village of Chapel Hill, boasting of no major industry other than the university and located somewhere near the boundary between the Piedmont and the Coastal Plain, commonly elicits comment from visitors for its fine trees, its simple and pleasing homes and gardens, its environment of forested slopes, the distant views of low hills and plain and a certain intellectual and social atmosphere which seems to be felt by even the most casual visitor.

Closely associated with the university

[2] Unfortunately this building was recently damaged by fire, but as expressed by a sympathetic faculty member, the "roastin' ears" remained uncooked and undamaged.



DR. HENRY VAN PETERS WILSON
KENAN PROFESSOR OF ZOOLOGY, UNIVERSITY OF NORTH CAROLINA, MEMBER OF THE ACADEMY.

is the Elisha Mitchell Scientific Society, named, like Mount Mitchell, in honor of Elisha Mitchell, professor of mathematics and natural philosophy from 1818 to 1825, professor of chemistry and mineralogy from 1825 to 1857 and state geologist for a time. The "Mitchell Society," founded in 1883 by a group of faculty members, has, from the beginning, published a "Journal," the fiftieth volume of which, appearing in 1934, marked the corresponding anniversary of the society. One of the features of entertainment will be a luncheon given by the Mitchell Society to the academy on the first day of the meeting, Monday, October 24.

Near at hand, only about nine miles away, is Duke University, and through numerous cooperative and friendly arrangements, graduate students and faculty of each institution may avail themselves of library facilities or actual instruction in the other. The academy will be entertained by Duke University for luncheon on Tuesday, October 25, and in the afternoon will be shown over the university and its environs.

Members of the academy at the University of North Carolina are H. V. Wilson, mentioned in an earlier paragraph, and Dr. Wm. de B. MacNider, formerly professor of pharmacology and now dean of the medical school.

R. E. Coker

Chairman, Division of Natural Sciences, University of North Carolina

THE NEW DIRECTOR OF THE CAVENDISH LABORATORY

Announcement has recently been made of the appointment of Professor William Lawrence Bragg, director of the National Physical Laboratory, as the successor of Professor J. J. Thomson in the headship of the Cavendish Laboratory at Cambridge.

Bragg's career has been striking from its inception. Born in Adelaide, South Australia, in 1890, he was educated at St. Peter's College and Adelaide University there, and went to Trinity College, Cambridge, as Allen scholar. Very shortly after taking his degree in 1912, he joined his father, Sir William Bragg, in the latter's x-ray studies in crystal structure, begun about that time as a consequence of the discoveries of von Laue. So rapidly and brilliantly did this work progress that within three years the Braggs were jointly recipients of the Nobel award in physics.

The war interrupted the Braggs's work in crystal structure, and the son undertook the organization and direction of the British sound-ranging service, universally acknowledged to-day to have been consistently in advance of that of any other army. With the conclusion of conflict, Bragg returned to Cambridge, and was appointed in 1919 to succeed Rutherford in the Langworthy chair of physics at the University of Manchester. Here he further developed his work in crystal structure and built up a very powerful working group in the field, which attacked crystal systems of ever-increasing complexity, culminating in the famous studies of the silicates. The Hughes Medal of the Royal Society was awarded Bragg in 1931 for this work.

Recently Bragg has become much interested in the study of metal alloys of considerable complexity, especially three-component systems, from the standpoint of lattice structure, and from this important field, largely initiated and built up by Bragg and Bradley and their co-workers and students, stem most of our present ideas concerning super-lattices and the "order-disorder" theory. In 1937 Bragg was called to fill the post of director of the National Physical Laboratory at Teddington, and his new re-

PROFESSOR WILLIAM LAWRENCE BRAGG

sponsibility at the Cavendish comes to him after but a year in that office.

The Cavendish Laboratory has become so large that no one man can control it closely to-day. When one considers the long list of brilliant researches and brilliant workers that have been identified with the Cavendish since Maxwell accepted its directorship in 1874, it is hard to realize that two great physicists, Sir William Thompson and von Helmholtz, refused the post before it went to Maxwell, on the ground that there did not seem enough promise of development. Yet such seems to have been the case. Through the five years of Maxwell's directorship, however, and through the succeeding directorship of Lord Rayleigh, the Cavendish steadily increased in number of workers and in the volume and quality of the work which was produced. It was already famous when its directorship passed into the gifted hands of Sir J. J. Thomson, in 1884. And under the influence of this man, who of all leaders of the Cavendish has been linked the longest and most intimately with its history, it attained much of the preeminence which it enjoys to-day. That prestige continued to grow rapidly when Rutherford succeeded to Thomson's directorship in 1919, and steadily increased throughout his lifetime. The Cavendish has always been closely connected at once with theoretical studies and with those which directly affect practical affairs of living. Under its new leader it may be expected to be brought into even closer touch with the daily life of the world.

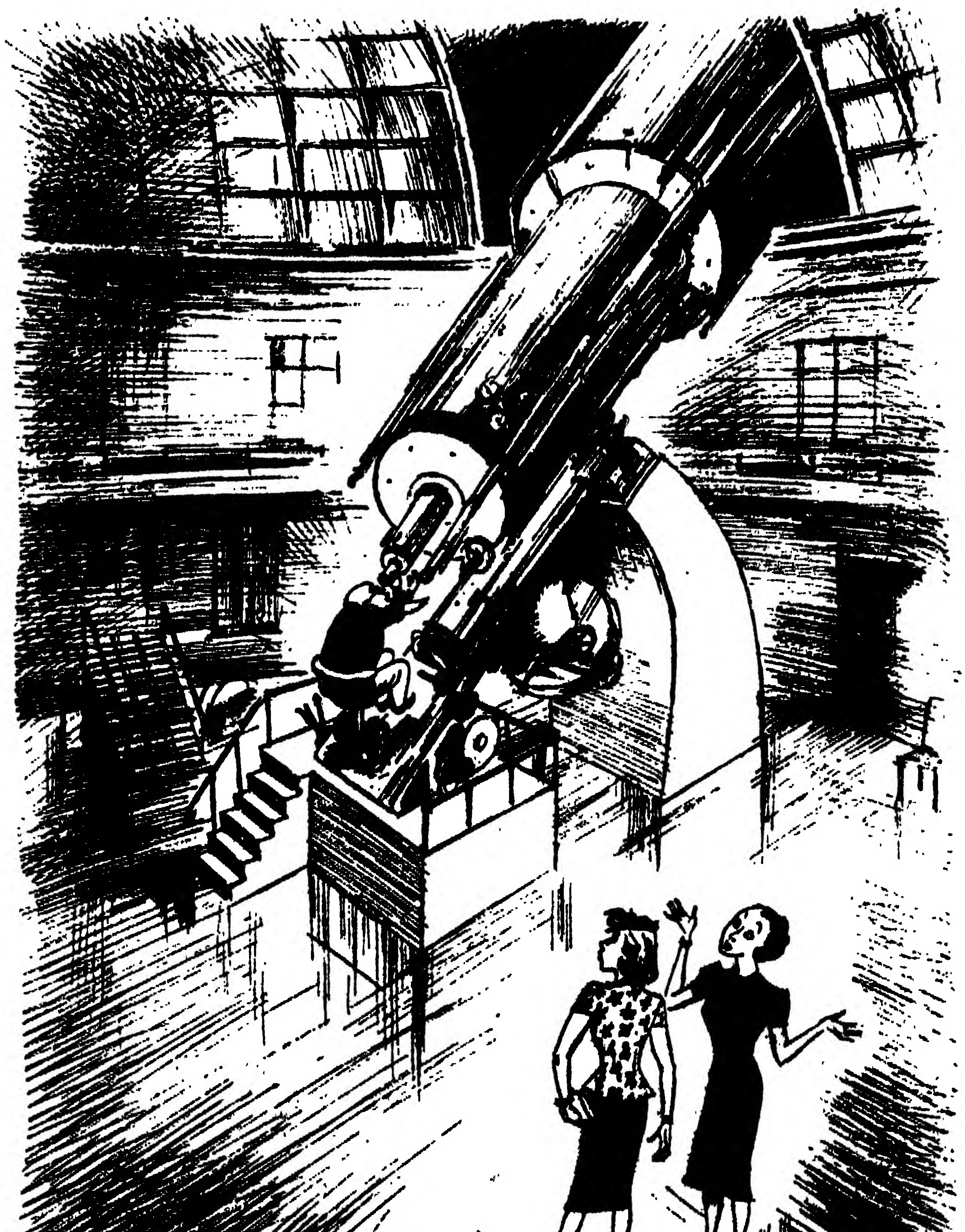
Caryl P. Haskins

Union College

THE CAVENDISH LABORATORY

THE PHOTOGRAPH SHOWS THE ORIGINAL WING BUILT BY MAXWELL AND OPENED IN 1874.

THE ASTRONOMER'S WORLD



—*From Punch.*

"MY HUSBAND LIVES IN A LITTLE WORLD OF HIS OWN!"

THE SCIENTIFIC MONTHLY

DECEMBER, 1938

DISEASE AND THE INDIAN

By Dr. JAS. G. TOWNSEND

DIRECTOR OF HEALTH, U. S. OFFICE OF INDIAN AFFAIRS

TALKS-WITH-THE-BEAR, the Crow Indian, is ill of an arrow wound. In the group of buffalo hide tepees where his band is gathered for the summer hunt there is no one who has heard of the white man's medicine, for this is in the early nineteenth century, when few white men live in Crow hunting country. The family of Talks-With-The-Bear send for the man who has had a vision giving him arrow wound power. His face painted with streaks of yellow and white, as his vision directed, this "doctor" comes to the door of the sick man's tepee, singing the song he dreamed. He paints the face of the patient and ties an eagle plume to his hair. He bids all the young men help in singing his powerful song, while he dances and strikes the ground with a buffalo tail. Then he and the patient bathe in the river. It was a clean wound and it heals.

Up on the coast of Washington, where the gabled houses of split cedar planks stand ranged along a river, a Quinault Indian lies sick of a wasting disease. His soul is gone, says the medicine man. So the "doctor" must send his own soul out to the land of the dead, a journey of many hours, even days, to find the sick man's soul and bring it back. He chooses a helper and they both lie down on a mat; while the helper shakes a rattle the "doctor" sings and all the bystanders help. It is a song taught to the "doctor" by the spirit which has given him power and it brings the spirit. While the bodies of the "doctor" and his helper lie apparently unconscious following this nervous frenzy, the spirit leads their souls to the land of the dead, where they catch the soul of the dead man—or they do if they are lucky and it has not gone too far. The "doctor" brings back the soul in his cupped hands and pours it into the patient's body through his head.

Farther south, in California, the medicine woman is called to an ailing child. An evil medicine woman, she says, has shot into him a "pain" shaped like a tiny rock crystal. She sucks the foreign object out of his body and even shows it to him. Down in New Mexico, where the stone houses of Zuni cluster among their cornfields, the sick man calls, not upon one medicine man but upon a whole society, for this is a highly organized town, one of the most complex of the ancient Indian world. The curing society sets up an altar in its whitewashed chamber and calls for help on the powerful animals who are so much more at home in the world than man finds himself. Finally they place bear paws on their hands and lay them on the patient, giving him the strength and endurance of the bear.

These are a few of the curing methods practiced by the Indians of North America before the white man came among

INDIANS OF THE BLACKFEET RESERVATION

ADHERING TO THE TRADITIONS AND THE COSTUMES OF THEIR ANCESTORS, NEVERTHELESS HAVE ADVANCED FAR IN THE WAYS OF MODERN PROGRESS DURING THE LAST FEW YEARS. SHOWN HERE ARE SOME OF THE STURDY SURVIVORS OF A GREAT RACE INDULGING IN THE SIGNIFICANT CEREMONIAL OF PASSING THE PEACE PIPE.

them. Various as the practices were, the theory of disease could be reduced to two main principles. Either some foreign object had gotten into the patient's body and must be sucked or charmed out or the patient's soul was gone and must be brought back by the medicine man. They were not such unreasonable theories. That of a foreign object in the body forms to-day an excellent basis for our modern knowledge of germs and that of a soul loss is not unsympathetic to the theories of the psychiatrist. Sorcery in different forms was also thought to produce a number of ailments besides the ones mentioned. So did breach of ceremonial rules, which could sometimes be cured by confession but more often by a new ceremony.

The treatment for any illness which was really serious was generally some version of song prayer and vision. But we can not scoff at their effect, for the patient who knew that his doctor had power from dreams gained thereby a perfect confidence in his own recovery. Modern physicians realize how valuable in connection with any treatment is the patient's conviction that everything is being done. But supplementing the forms of treatment which were chiefly magical, medicine men often used practical therapeutics in the form of massage, sweat baths and herb medicine. Sometimes the "doctor" with his powerful dream acted merely as diagnostician and turned over the actual treatment to some specialist who had learned his method of cure with or without dreaming. In one way or another and in different parts of the country there were Indian doctors who made use of emetics, cathartics, haemostatics, massage, bandaging, cauterization and splints. They knew the local herbs, both poisonous and beneficial, and our modern pharmacopoeia contains several drugs of Indian origin, such as cascara sagrada, coco from which cocaine is derived, hydrastis jalap, ipecac and Podophyllum.

The ailments with which these early practitioners had to deal were not the devastating communicable diseases which afflict a civilized population. The Indian population in hunting and food-gathering areas was about one person to the square mile. In such country the food-gathering peoples of California erected their temporary dwellings of brush and mud, usually destroyed after a death. The Algonquins of our Northeast set up their bark wigwams or the Sioux their tepees of buffalo hide. All these were frequently renewed and therefore free from accumulated filth of modern cities. Their inhabitants rarely collected in large groups and when they did the gathering was a temporary one, for hunting or ceremonies. Even had an epidemic begun among them, it could not spread far.

In agricultural communities larger numbers of persons lived together, but rarely in groups of more than two or three hundred. The Iroquois of New York State had their stockaded villages, where the long houses of elm bark might accommodate six or eight families, housed in two rows, as in the compartments of a sleeping car. The Mandan lived in domed earth-covered dwellings, warm in winter and cool in summer. The people of the Pueblos, the most highly civilized of all, had square-built rooms of stone or adobe, piled on one another like a modern apartment house. Here was some approach to the white man's conditions, but the saving grace was that even the village Indians were outdoor people. Their business was agriculture and the men—or often the women—were in the fields from morning to night. Those who worked at crafts, such as pottery, skin dressing, basketry, arrow-making, were usually out of doors in the sunshine. Their clothing was scanty. California men wore nothing, Pueblo men only a breechclout; women usually had arms and legs bare. Even the Indians of colder climates had their skins exposed

to the sun rays in warm weather, as do the health seekers on beaches to-day. Their food, according to the locality where they lived, was meat, fish, vegetables (often eaten raw), nuts, seeds and fruits. Few areas had all these possibilities but, since Indians ate every part of an animal and every edible plant in their locality, they came nearer a balanced ration than might be supposed.

Sometimes they did suffer from malnutrition on errors of diet and sometimes their arduous life exposed them to pneumonia, arthritis or injuries through accidents. Indeed the preponderance of female skeletons in Indian burial places would indicate that the majority of males were killed in battle or while out on the hunt. But on the whole, says Dr. Hrdlička of the Smithsonian Institution, America, before its discovery by Columbus, was one of the most healthful of continents, if not the most so.[1] His studies have shown that skeletal remains of that time are, barring a few exceptions, remarkably free from disease. Apparently there was no rachitis, no proved tuberculosis, no smallpox, measles or trachoma; cancer was rare, and even fractures infrequent. Furthermore, there is as yet not a single instance of thoroughly authenticated pre-Columbian syphilis. Even in the childhood of Indians now living, these white man's diseases were rare in the remoter localities. I have been informed in personal conversation with some older Indians that in their early youth they knew nothing of either trachoma or tuberculosis.

All this was changed when the white settlers swept across America, bringing diseases old in Europe but new and deadly to the Indians. Even before the Pilgrim Fathers landed on Plymouth Rock, smallpox had been brought to New England by coasting vessels or perhaps by the French to the north. One reason the Puritans were allowed to settle so peacefully was that the near-by Indian village had been abandoned because of the epidemic. Back through the forest country the epidemic had made its way until the deserted Indian village sites seemed, said an early trader, "like a new Golgotha," littered with bones and skulls.

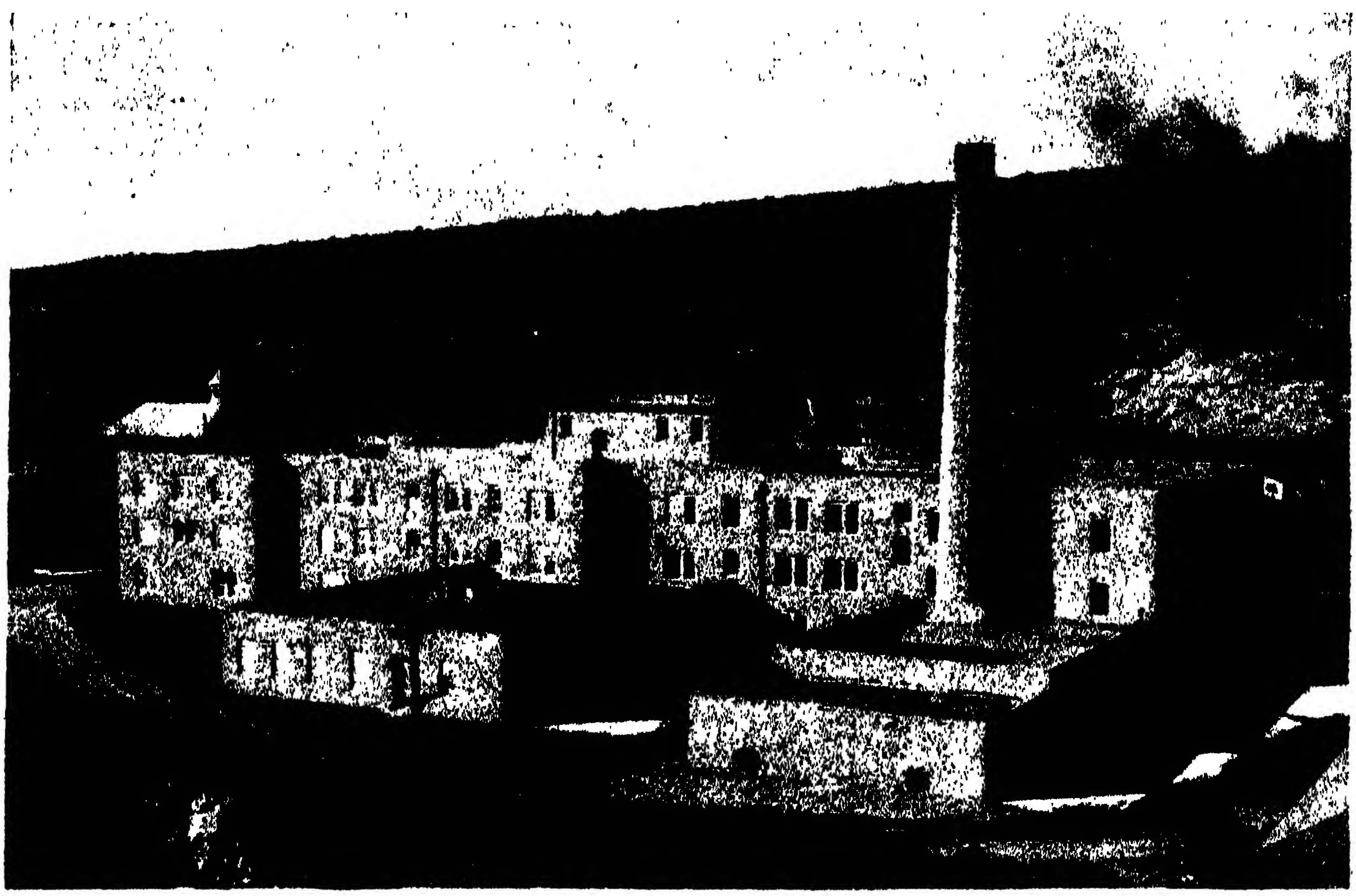
Against a cataclysm like this the prayers and the consolation of the medicine man were completely unavailing. The susceptible, unvaccinated Indians died off until the Massachusetts tribe was reduced from 3,000 to 1,000. As far south as the Delaware River villages were abandoned, never to be revived.

As the pioneers moved west the disease moved ahead of them. We learn from Schoolcraft[2] of conditions which read like pages from John Evelyn or Boccaccio of the bubonic plague in Europe. According to the records, smallpox swept through the Missouri Valley in 1837. An employee on a Missouri River steamboat was the initial focus. From him it became epidemic at a trading post about 500 miles above St. Louis. Precautions were taken by sending Indian runners to the Indian camps two days ahead of the boat but to no avail. The Mandans, a tribe consisting of 1,600 persons, were reduced to 31. The Minnetarees, living in that vicinity, were next attacked and of 1,000 of this tribe, 500 remained. Of 3,000 Arickarees, only 1,500 survived. Then it spread to the Assiniboins, Crows and Blackfeet. To quote one paragraph from this account:

> Granting everything that can be asked on the score of excitement and exaggeration, not less than 10,000 persons fell before this destroying disease in a few weeks. An eye-witness of this scene, writing from Fort Union on the 27th of November, 1837, says: "Language, however forcible, can convey but a faint idea of the scene of desolation which the country now presents. In whatever direction you turn, nothing but sad wrecks of mortality meet the eye. Lodges standing on every hill, but not a streak of smoke rising from them. Not a sound can be heard to

[1] *Journal of the American Medical Association*, November 12, 1932.

[2] "History, Condition and Prospects of the Indian Tribes of the United States," Vol. I., 1853.



THE NEW INDIAN GENERAL HOSPITAL AT FORT DEFIANCE, ARIZONA

break the awful stillness save the ominous croak of ravens and the mournful howl of wolves, fattening on the human carcasses that lie strewed around. It seems as if the very genius of desolation had stalked through the prairies and wreaked his vengeance on everything bearing the shape of humanity."

As allies of smallpox to further smite these people were tuberculosis, venereal diseases and trachoma, which will be discussed severally in this narrative.

As early as 1824 the Bureau of Indian Affairs was organized in the War Department, as the Government apparently recognized the multitudinous problems occasioned by the wardship of another race. When the Department of the Interior was created by the Act of 1849, the Bureau (now called Office) of Indian Affairs was made a part of this new department and the administration of the Indian Office passed from military to civil control. It was not until 1924 that there was actually organized in the Office of Indian Affairs a division of health. Two years later, cooperative relationships were consummated with the Public Health Service, whereby the Director of Health for the Indian Service was selected from that corps, as well as a limited number of field supervisors. The medical organization of the Indian Office in brief consists of the director of health, an assistant director, a hospital administrator, a pharmacist, a part-time supervisory dental surgeon and a director of nursing. These are in Washington. In the field there are found medical directors acting as advisers in certain areas, special physicians in tuberculosis and trachoma, general physicians, dentists and nurses in hospitals and engaged in public health, also a certain number of supervisory field nurses at large. Indian women entered the field of professional nursing as early as 1890. Many practiced among the white population exclusively, others returned to their community or entered the Indian Service. At the present time about 15 per cent. of our total nursing force is Indian, either in part or full blood. The two racial characteristics that are predomi-

nant and useful in this occupation are their manual dexterity and their imperturbability.

A school for nurse aids has been established at the Kiowa Hospital in Lawton, Oklahoma. It is found useful to give training to young women as subsidiary hospital personnel. They are employed, after nine months of supervised experience and training, in the wards of the hospital as aids to the professional nurses. This training and experience does not qualify them to exercise professional judgment nor to take full responsibility for the care of patients, but it materially increases their skill and understanding of hospital work and the care of sickness. They give baths, take temperatures, helping in many ways to extend routine nursing care, thus conserving the time of the professional nurse for duties demanding her greater skill. This school has been operating for two years and we find that it has been practically useful in furnishing a better type of hospital personnel; also it has been an incentive to Indian young women to go into the professional field of nursing. Most of the selections are made from high-school graduates so that they can go further if they so desire. The total field force is approximately 1,700 employees. The patients of this medical group represent a people numbering about 350,000 belonging to 230 tribes and scattered throughout the Union in 26 States on 200 reservations.

These potential patients of the Government do not now represent a distinct ethnic group which has maintained its original racial characteristics and customs. In many sections there has been a blending of races and a modification of customs. However, in certain sections of the Southwest and Florida the Indians live very much as when found by the early Spanish settlers, while in many parts of Oklahoma they and the whites live on adjoining properties and participate equally in political and social affairs.

Tuberculosis is the great Indian killer. A perusal of the literature regarding the extent of tuberculosis infection among Indians in the years gone by reveals much that has been written, but comparatively little which can be used as a definite basis for comparison as to what the morbidity rate was years ago and what is found at the present day. As early as 1633, references are recorded of the observations of the Jesuit Fathers. In that year, speaking of scrofula, one observer says, "They are nearly all attacked by this disease when they are young." This reference to scrofula among Indians is predominant for the next hundred years. On the other hand, we find a reference in 1794 by Dr. Benjamin Rush to the effect that "It (pulmonary consumption) is unknown among Indians of North America" (a statement which has been challenged).[3] Lewis and Clarke in a report of their travels from 1804 to 1806 state that the Indians are "generally healthy, the only disorders which we have had occasion to remark being of a scrofulous kind." J. G. Hunter, in an article appearing in the *American Medical Record,* Philadelphia, 1823, says in part, "I have known pulmonary consumption to occur among the Indians. It is rarely seen, however, except in those who are addicted to intemperance, and even in these it is by no means so common as among the whites." Dr. Matthews, of the United States Army, who has written much on early tuberculosis among the Indians, reports that in 1865 among the Indians of Dakota and Montana consumption was but little known. These same Indians were observed 22 years later by a Dr. Treon, who stated that "The first diseases to which my attention was directed when I reached the Agency were consumption and scrofula."

These speculations as to the origin of tuberculosis among Indians of the North

[3] Stephen Maher, *American Review of Tuberculosis,* 1929.

INDIAN TUBERCULOSIS SANATORIUM AT SHAWNEE, OKLAHOMA

American continent are interesting as conjecture and speculation, but it is as difficult to explain satisfactorily as is the origin of any other disease. We can summarize the literature by the statement that tuberculosis did exist to some degree in the Indians while they were living in their natural state in post-Columbian times, and that the spread of this disease was greatly enhanced when they were forced on reservations, living in closer proximity with one another and with the whites, and under domestic environments which were quite different from those to which their ancestors had been accustomed. This, together with the fact that they had not made peace with the tubercle bacilli through years of hereditary immunity, has caused this disease to spread rapidly among them and with devastating results.

Attempts have been made to determine the tuberculosis rate through general clinical surveys. In a series of group surveys from 1927 to 1932, there is record of 17,169 Indians examined, all ages, with 1,730 positive cases reported. This would give an incidence of 10 per cent., with the childhood type of tuberculosis included. We do know that the mortality rate is high and on this point there are definite figures. More Indians die from the disease in the North and Northwestern States than in the South and Southwestern areas. In 1935 there was an estimated Indian population of 106,420 in the States of Idaho, Iowa, Minnesota, Montana, Nebraska, North Dakota and Oregon. Among this group in one year the reported death rate from tuberculosis was 213.3 per 100,000. In that same year there were reported 119,223 Indians in the States of Arizona, California, Colorado, Kansas, Mississippi, Nevada, New Mexico, North Carolina, Oklahoma and Utah. Among this group the death rate was 204.7 per 100,000. It is known that the death rate from tuberculosis among Indians is from three to four times greater than among the whites, dependent on locality. It is as yet extremely rare to find tuberculosis among the Seminole group living in the Florida Everglades.

A very interesting survey was accomplished by the Cattaraugus County Department of Health, New York State, in cooperation with the Indian Service, on the Alleghany Indian Reservation in 1935. Six hundred and fifty Indians

were examined in a population group of 972. In a personal communication to the writer, Dr. Korns, at that time director of the Bureau of Tuberculosis (who, with Atwater, conducted the survey), had this to say: "The County Department of Health was relieved of the suspicion that there might be numerous foci of tuberculosis spreaders in the reservation; the findings do not warrant that suspicion. The x-ray films showed considerable ability to build up fibrous tissue and this is encouraging to health work. These Indians do not seem to constitute 'virgin soil' for tuberculosis infection any more. I was impressed with the sturdy rather robust nature of most of the adults. They have fewer postural defects than the white persons I see in clinics."

In that same year, Long, of the Phipps Institute and tuberculosis consultant for the Indian Office, conducted a similar survey in cooperation with the Indian Service on the Papago reservation in Arizona. In this survey 530 Indians were examined. In the published report[4] is this statement: "Taking into account the character and extent of lesion as well as the scarcity of significant progressive disease of the childhood type, we feel that pulmonary tuberculosis among the Indians studied conforms more closely to the type of pulmonary tuberculosis seen in white patients at the Henry Phipps Institute than to the massive and rapidly progressive type more often seen in negro patients."

These two independent observations in different sections of the country are encouraging in that there is reason for belief that the Indian race is gradually building up a resistance against tuberculous infection.

The State Board of Health of Montana has made interesting studies on the reservations in that state which show definitely that there was a higher incidence of tuberculosis among the full-blood Indians examined and that this index progressively dropped in proportion to the white admixture of blood. The same is also true of the mortality rates.[5]

The Indian Service is striving to meet the problem through education and hos-

[4] "A Tuberculosis Survey in the Papago Indian Area of Southern Arizona," Esmond R. Long and H. W. Hetherington, *Supplement to The American Review of Tuberculosis*, March, 1936.

[5] "A Study of Tuberculosis Among the Indians in Montana," by J. H. Crouch, M.D., C.P.H., Montana State Board of Health, Public Health Reports, U. S. Public Health Service, Sept. 16, 1932.

SAN XAVIER INDIAN TUBERCULOSIS SANATORIUM, TUCSON, ARIZONA

TRACHOMA TREATMENTS AT THE CHEMAWA INDIAN SCHOOL, OREGON

pitalization. There are 81 general hospitals and 14 tuberculosis sanatoria. The total number of beds in the tuberculosis sanatoria is 1,421. Besides, approximately 1,700 tuberculosis patients are treated in general hospitals, a number of the newer ones having tuberculosis wards.

Educational activities through the medium of the field nurse and field physician are responsible often for bringing about hospitalization, while an educational program during the time the patient is taking treatment is utilized. Pneumothorax is a type of treatment to which the Indian responds and is becoming more widely spread as the Indian Service physician is trained in this technique. Special physicians who have been trained at the Phipps Institute are conducting surveys with the assistance of specially trained tuberculosis nurses in an effort to find a true picture of tuberculosis incidence and the classification of cases. Those who can be given pneumothorax injections are so treated; others who need hospitalization are provided for and the school authorities and parents advised of the childhood type of the disease when found for special consideration of that individual child. It will be some time yet before the Indian race approaches the lower morbidity as found among his white brothers, for the whole problem is so interwoven and entangled with economics and poverty that many other lines of approach will have to be encouraged and consummated before our ultimate goal in the control of tuberculosis among the Indian race is really reached.

Of 5,342 pupils, average age 13 years, representing various tribes in 30 different localities in the Southwest, 74.1 per cent. showed a positive tuberculin test. In four non-reservation boarding schools, Santa Fe, Albuquerque, Fort Wingate and Phoenix, in which are found the older groups of pupils, the average age being 17 years, the positive rate averaged 90.6 per cent., this in 1,700 pupils. In the reservation schools, where the average age was approximately 11 years, the positive rate was 65.6 per cent.

When the Indians first developed trachomatous eyes is unknown. It is not

A TRACHOMA CLINIC

remembered by the older ones as being prevalent, although old records do call attention to "bad eyes," conjunctivitis, scrofulous eyes and terms of that nature. The theory has been advanced that Coronado at the time of the invasion of Arizona and New Mexico in the early sixteenth century might have been the cause of its introduction, but this is purely conjecture. However, we do know that it is much too prevalent among this racial group on the North American continent —unusually high when consideration is given to the general rate among the white race in the United States.

The first systematic survey to determine the prevalence of this condition was accomplished in 1912, when the Public Health Service[6] undertook a complete survey of the Indian population. All states were visited where Indians reside, and a total of 39,231 Indians were seen. Of this number, 8,940, or 22.7 per cent. of the entire number, were found to be infected. This included both sexes in all ages. The degree of infectivity varied in this record according to locality from as high as 68.7 per cent. in Oklahoma to none in Florida. It is unquestionably true that the rate has been materially reduced since that time. Among 17,320 examined in group surveys, all ages, on 24 reservations, between 1927 and 1931, 1,213 positive cases were found, or 8 per cent. The disease does vary remarkably according to tribe. The highest infection group now is the Navajos, in Arizona, where approximately 30 per cent. are infected, whereas among the Florida Seminoles there has never been a case reported, nor is trachoma found among the Taholah group at Neah Bay in the northwest tip of Washington State. Quoting from a report prepared by Mountin and Townsend[7] while on a survey in 1934: "Miscellaneous groups in Wisconsin, those at Cherokee, North Carolina, and at Cloquet, Minnesota, show practically no trachoma. In Oklahoma probably less than 5 per cent. have the disease. Among the Mission Indians of Southern California, it runs about 3 or 4 per cent. In the Northwest there is little trachoma west of the Cascade Mountains, but among the Flathead,

[6] "Contagious and Infectious Diseases among the Indians," Senate Document No. 1038, 62d Congress, 3d Session.

[7] "Observations on Indian Health Problems and Facilities," by Surgeon J. W. Mountin and Senior Surgeon J. G. Townsend, U. S. Public Health Service Bulletin No. 223, Feb., 1936.

Blackfeet and other Montana tribes, 20 per cent. or more of the Indians show evidence of the disease. In the Dakotas about 5 per cent. of the Sioux have trachoma. The Chippewas in Minnesota have less. In the Southwest the same differences are to be found among the several tribes. For example, at Zuni fewer than one per cent. of the Indians have trachoma, while in the pueblos about Laguna the incidence runs from 16 to 25 per cent. About 30 per cent. of the Navajos show evidences of trachoma and the same is true of the Apaches at San Carlos and Fort Apache; but, curiously enough, a recent survey of the Apaches at Jicarilla revealed only one per cent. of the Indians to be afflicted with the disease."

This peculiar incidence, especially when a high infectivity rate is noticed in one tribe contiguous to another tribe where the rate is almost nil, and yet social intercourse and free intermingling prevail, is a matter that warrants further study and research.

The trachoma activities in the Indian Service are organized under a medical director in charge and a corps of special physicians trained in the work, who visit reservations and schools for the purpose of rendering treatments. They are accompanied by specially trained nurses. These physicians also act as consultants to the local physicians at the various field stations.

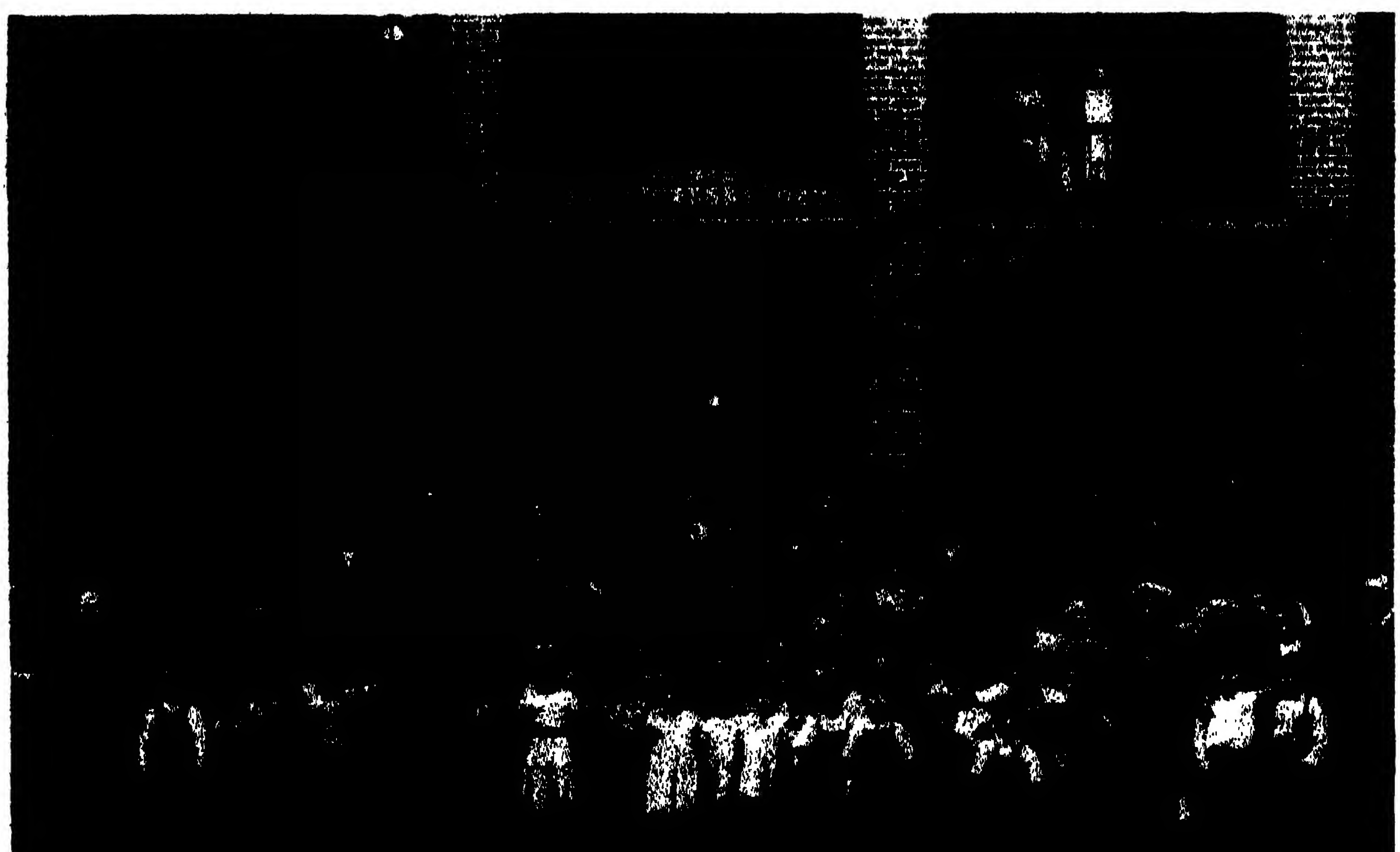
There is maintained a special trachoma school on the Fort Apache, Arizona, reservation, and at this place, in cooperation with Columbia University, research studies for the past few years have been carried out on the etiology of this disease. By the concentration of trachomatous children here for the past three years trachoma has been practically eradicated from the school group on this reservation. Much yet has to be done in education and intensive treatments, especially among the adults.

Next to tuberculosis, the great enemy of the Indian is the high infant mortality rate. The last available report shows an Indian infant death rate per thousand live births one year of age and under of 97, whereas the rate in the registration area is 56.9. This condition is due primarily to dietary disorders and contagious diseases of childhood, predominantly measles and enteric infections. With this high infant death rate, however, there is an encouraging note in the fact that the general birth rate is 23.8 per thousand and the general death rate 16.4 per thousand, which gives the Indian a favorable balance and insures his perpetuity.

Studies have been carried on in New Mexico for several years on diarrhoeal disorders among Indian, Spanish and white groups. This was made possible through the cooperation of the Public Health Service, the Indian Service and the DeLamar Institute of Public Health, Columbia University. Among the Indian groups a high percentage were found to harbor the amoeba hystolitica, the cause of amoebic dysentery, and also the bacilli of Shiga and the bacilli of Flexner, causing infectious diarrhoeas. For example, in a group of 382 Indians examined in seven localities in New Mexico, 40.2 to 18 per cent. harbored the amoeba in the intestinal tract. These studies are being pursued and experimental areas selected for preventive measures by the use of sanitary privies. In one area in a population of 1,000 and with 28 cases of acute diarrhoea reported, of which 14 had infectious dysentery, and with a total of 250 of the general population examined with 7.2 per cent. yielding specific organisms, the following year after the installation of these sanitary precautions there was only one case of diarrhoea reported and that was mild. It is trusted that these studies will lead to further effort elsewhere.

The venereal diseases are difficult to

INDIAN CHILDREN IN THE TUBERCULOSIS SANATORIUM ON THE JICARILLA-APACHE RESERVATION, NEW MEXICO



ONE OF THE SPECIAL INDIAN SCHOOLS WHERE TRACHOMATOUS CHILDREN ARE SENT FOR TREATMENT. A GROUP OF YOUNG PATIENTS AT THE CHEMAWA INDIAN SCHOOL

measure accurately. As would be expected, the higher incidence is near the population centers, the less incidence in the far-away places. From Wassermann surveys done indiscriminately at the time of examinations, the incidence, including all degrees of plus reactions, is about 8 per cent.—higher than the white but lower than the Negro race. Of scientific interest is the observation that syphilis does not do appreciable damage to the central nervous system of the Indian. General paresis, locomotor ataxia and gummata are rare. Nor does syphilis seem to measurably affect the cardiovascular system of the Indian. This observation is worthy of further study.

Venereal diseases are being treated routinely when found and for this purpose the out-patient clinics are utilized. A large clinic is now in operation at Anadarko, Oklahoma, as an example, and among the Osage tribe at Pawhuska, Oklahoma, is a modern clinic for diagnostic purposes which is supported entirely from tribal funds. This health clinic is the result of the voluntary desire of the Osages to have this service and they could afford to pay for it. Emphasis is placed elsewhere on the routine Wassermann examinations of all patients entering hospitals and of expectant mothers.

Malignancy among the Indian race has intrigued investigators for some time. In 1921 Hoffman, consulting statistician of The Prudential Insurance Company of America,[8] made an exhaustive compilation of what figures were available as to Indian cancer mortality. He reported during the five-year period 1921–1925 that 2.34 per cent. of Indian deaths in the registration area were due to this cause, in comparison with an 8 per cent. cancer death rate in the total registration area, all races. These figures were not based on population as figures at that time were not reliable, but Hoffman indicates that this would indicate an average frequency of 55 per 100,000. In 1925, for the whole registration area, the rate was 92.6 per 100,000. It was higher in females and was more common in the involvement of the stomach and liver, 45.6 per cent. in Indians as compared to 37.6 per cent. in whites. Among Indian females the generative organs were involved in 19.9 per cent. of cases, as compared to 14.1 per cent. in whites, but breast cancers were more common in whites, with a ratio of 9.1 per cent. compared to 4.7 per cent. among the Indians.

Then in 1936 Dr. E. Payne Palmer,[9] of Phoenix, Arizona, made a similar study. He based his rates on population studies and noticed an increased rate in both races, white and Indian, in 1928–1933. In 1933 the white rate was 97.6 per 100,000 and the Indian 42. He confirms Hoffman's report of a high incidence of stomach cancer among Indians and whites, but includes in this the duodenum (54.9 per 100,000 for Indians, 281 for whites). In these studies the involvement of the female generative organs was higher among whites than Indians. There is also confirmation that there is a higher incidence of breast cancer among whites than among Indians, being 59.4 per 100,000 among whites as against 12.3 per 100,000 in Indians.

The Health Division of the Indian Service has reviewed this paucity of cancer cases among the Indian race in comparison with the white and there are possibly two factors which should be considered:

(1) Before any intensive medical care or public health work was carried out among Indians their expectancy of life was not as long as that of the whites and therefore many did not reach the cancer age.

[8] "Cancer among North American Indians," Frederick L. Hoffman, LL.D., The Prudential Insurance Company of America, Newark, N. J.

[9] "The Incidence of Cancer among the Indians of the United States and Canada," E. Payne Palmer, M.D., F.A.C., Phoenix, Arizona.

(2) The failure to diagnose incipient cases.

A more intensive hospitalization program now in vogue and the development of post-mortems and tissue examination may change the picture somewhat, but even so, this disparity of rates should stimulate more intensive study and research in this phase of Indian health.

Dr. Paul, from the Department of Medicine, Yale University,[10] completed a study in 1936 on the prevalence of rheumatic heart disease among Indian school children. He found that among the northern tribes between the Canadian line and the southern border of Wyoming the rate in 6,088 children was 45 per thousand. In the middle zone, extending to the middle of New Mexico and Arizona, in a group of 1,106 children the rate was 19 per thousand, while in the southern zone, extending to the Mexican line, in a group of 1,019 children the rate was only five per thousand. This study was undertaken to determine the effects of climate upon this disease.

In addition to conditions described, the Indians as a race bear with the general run of human ills in about the same proportion as the whites. Influenza has its seasonal march, being responsible for 34.6 per cent. of the 40,980 contagious and infectious diseases reported in the fiscal year 1937, with impetigo 16.4 per cent. The smallpox incidence was 0.1 per cent., typhoid and paratyphoid .3 per cent.; and diphtheria 0.2 per cent. These rates are average. These latter three plagues are controlled by biological immunization and find a more ready acceptance among Indians than in certain white groups. The white race can learn much from the Indian in practical smallpox control.

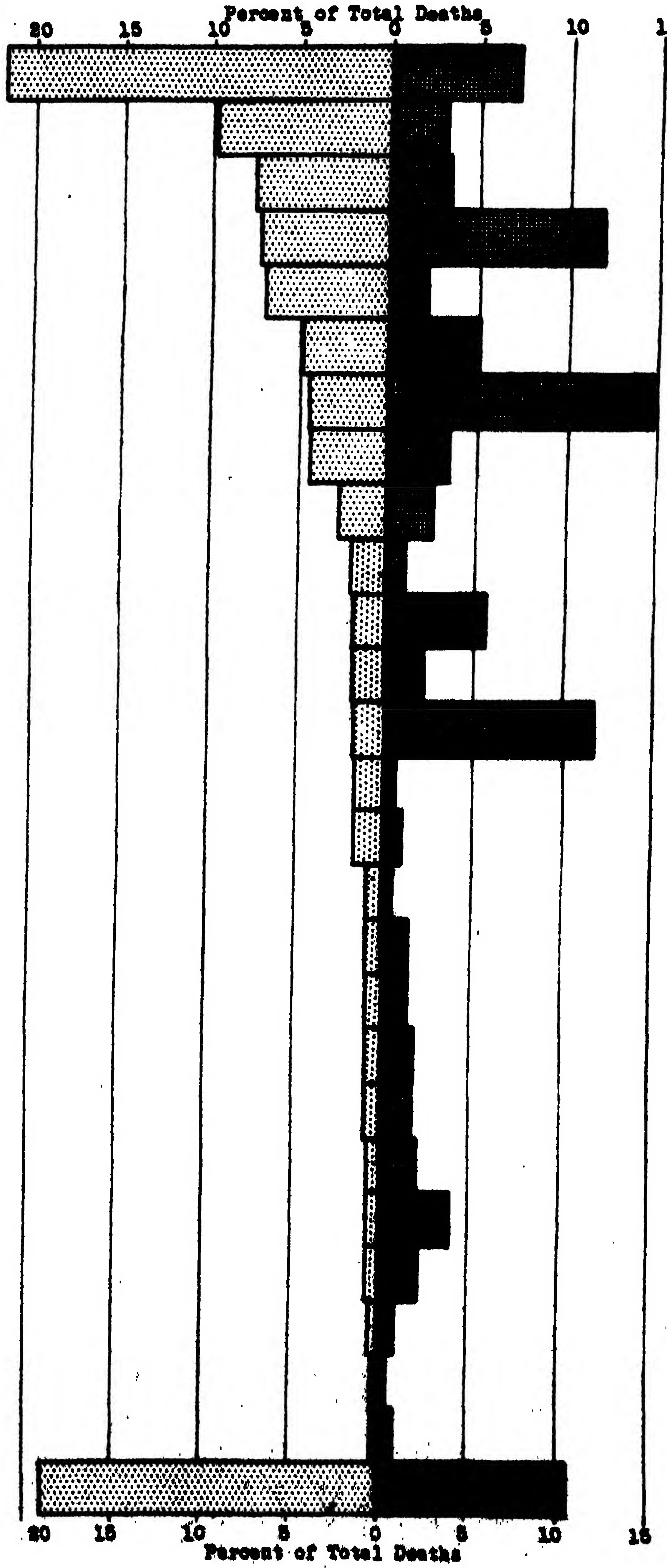
The bar graph of deaths by selected causes in the Indian race and in the total registration area shows a relativity of mortality incidence which is true to-day. The Indian race is handicapped with certain conditions described but does not suffer in the same proportion as the white race from cardio-vascular changes, malignancies, nephritis, and should have more security from the accidental deaths so commonly seen in large cities and in thickly populated centers.

During the last four years there has been a renaissance in modern hospital construction in the Indian Service, due to special appropriations and special governmental grants. The Indians in increasing number are utilizing these facilities. This may be exemplified in the obstetrical services. In 1930, of 4,118 live births reported, 26.6 per cent. of babies were delivered in Indian hospitals. In 1937, of 5,654 live births reported, 59.6 per cent. were hospital deliveries, and the years have shown a steady increase even before 1930.

Dentistry is practiced among Indian groups on a limited scale, there being only 14 dentists on a traveling status and a few full-time and contract dentists operating in hospital units. The itinerant dentists cover contiguous states, visiting various reservations and school centers. Of necessity the emphasis is placed on the treatment of the child, although adults are treated in emergencies and to relieve pain. The dental caries rate among tribes varies according to locality and seems to be in ratio to certain dietary habits. The condition is not so common among meat eaters. Among the Navajos, where there is a low incidence of dental caries, their main subsistence is milk and mutton. The Apaches have a low incidence, subsisting largely on beef, and the same may be said of the Pima tribe in Arizona. Among the Pueblo groups in New Mexico, however, we find at least three times as much caries as among the Navajos. These people eat starchy foods, sweets,

[10] "Climate and Rheumatic Heart Disease," John R. Paul, M.D., and Geo. L. Dixon, M.D., *Journal of the American Medical Association*, June 19, 1937, Vol. 108, pp. 2096–2100.

CAUSE OF DEATH	NO. DEATHS U.S. TOTAL	NO. DEATHS INDIAN
Total	1,396,903	5,662
Heart Diseases	303,724	396
Cancer and Tumors	134,428	165
Nephritis (all)	106,584	165
Pneumonia (all)	100,573	666
Cerebral Hemorrhage	97,148	113
Cong. Mal. and Infancy	66,988	287
T.B. Respiratory	64,606	840
Other Viol. and Acc.	64,370	187
All Auto Deaths	35,759	137
Diabetes Mellitus	28,000	49
Diarrhea and Enter.	23,201	310
Influenza	21,868	110
Ill Defined Causes	20,929	663
Suicide	18,828	35
Appendicitis	18,129	52
Hernia	13,023	44
Pregnancy and Childbirth	12,859	72
Homicide	12,065	65
Syphilis	11,726	86
Senility	10,961	83
Whooping Cough	7,518	119
Measles	6,986	187
Other T.B.	6,903	116
Typhoid and Paraty.	4,837	45
Alcoholism	3,655	21
Dysentery	3,373	46
All Other	198,472	584



DEATHS BY SELECTED CAUSES—1934

THIS GRAPH PRESENTS TRENDS WHICH HAVE NOT CHANGED. IN THE TOTAL NUMBER OF DEATHS REPORTED, ALL AGES, IS THE HIGHER MORTALITY FROM CARDIO-VASCULAR DISEASE, CANCER AND NEPHRITIS; AMONG INDIANS, PNEUMONIA, TUBERCULOSIS, DIARRHOEA AND ENTERITIS, MEASLES, AND THE ILL-DEFINED CAUSES (THE LATTER DUE TO DIFFICULTY IN ACCURATE DIAGNOSIS WHEN MEDICAL CARE IS NOT AVAILABLE) PREDOMINATE.

LAST RIDER AND HIS WIFE

SHOWN HERE IN TRADITIONAL BLACKFEET DRESS, STILL BELIEVE THAT THE TEPEE IS AN EXCELLENT TYPE OF HOUSE.

jams and candies. Also among the Chippewa tribes in Minnesota and Wisconsin, with a high caries rate, the subsistence is mainly vegetables and wild rice. The North Dakota Chippewas, however, with a low caries rate, have more milk and meat. Further examples could be given, but these will suffice.

Dental trailers have been introduced in the Service and, roads and weather permitting, have proved of immense value, being in reality completely equipped dental offices on wheels. As in other human ills, dental caries opens a field in research among the Indian people which might well be explored.

Public health progress through health clinics and education and home visits by the public health nurse are developed as rapidly as funds and personnel will permit, and whenever possible it is the goal that these programs gear in with local health services, as furnished by the county and state board of health. It is felt that the states have definite responsibility for the health protection of a racial group within its borders and in cooperation with the Government this plan is in successful operation in some jurisdictions. Many states have designated Indian Service physicians as local deputy health officers, with the reservations open to state health personnel, to assist in control of diseases that know no boundary lines.

And so to-day we find the Indian with a better knowledge of his physical ills and meeting them more successfully than in the past. He can be reassured in the facts that his race is definitely increasing and that his medical services are far above the average seen among the needy whites. There is much yet to be done, but in all these endeavors he is becoming better able to reach the mean level of economic security and to contribute to the public health welfare of the whole country, this in contrast with what he experienced when the white race "discovered" him.

LUMINOUS GEMS, MYTHICAL AND REAL

By Dr. SYDNEY H. BALL
NEW YORK, N. Y.

MARTIUS reports that Bassianus lies dead in "this detested dark blood-drinking pit."

> *Quintus:* If it be dark how dost thou know 'tis he?
> *Martius:* Upon his bloody finger he doth wear
> A precious ring that lightens all the hole,
> Which, like a taper, in some monument,
> Doth shine upon the dead man's earthy cheeks
> And shows the rugged entrails of the pit."
> —*Shakespeare,* "Titus Andronicus," Act II, Scene 4.

Ancient and medieval histories and the folklore of all time spin many a tale of luminous gems, rubies, garnets, emeralds, olivines and diamonds and even the pearl so bright in many cases as to be a reasonable substitute for a battery of electric light bulbs. The variants of these tales are many, about one hundred being known to the writer.

Some gems indeed do glow in the dark after being excited by friction or heat: if the glow continues beyond the period of excitation, the phenomenon is phosphorescence: if the glow ceases with the excitation, it is fluorescence. Practically all diamonds, if rubbed with a cloth, and a few diamonds, after being exposed to direct rays of the sun, glow in the dark. Again diamonds and white topaz if heated below red heat may phosphoresce. The phosphorescent quality of diamonds when heated by the sun's rays is usually believed to have been first discovered by Albertus Magnus (?1206–1280) and it was apparently rediscovered by Sir Robert Boyle in 1663. Boyle also found that one diamond when pressed with a steel bodkin emitted light. Praphulla Chandra Ray, however, claims with apparent justice that Bhoja, a Hindoo of the eleventh century, knew that diamonds phosphoresce. Du Fay, in 1735, determined that lapis lazuli and the occasional emerald and aquamarine were luminescent. Wedgewood, in 1792, found that two pieces of rock crystal or of agate, rubbed against one another, phosphoresce. Pott some fifteen years earlier knew of the luminescence of rock crystal. Wedgewood also states that the ruby gives "a beautiful red light of short continuance." Edmond Becquerel, in 1861, reports that ruby fluoresces better than sapphire. Red felspar fluoresces and when some adularia is crushed the powder fairly flames. From the character of the fluorescence produced by cathode rays, the country of source of a genuine ruby can be determined as can the factory from which a synthetic comes. Many other gems glow if treated with ultra-violet, cathode or x-rays, or with radium emanations: but these are all too recent additions to science to have influenced the authors of the myths of luminous gems.

The discovery of the fluorescence of the mineral from which the property gains its name, fluorite, is usually ascribed to Sir David Brewster in 1833. But Philip Skippon[1] states that one Monsieur Lort, of Montpellier, France, a "counterfeiter" of "amethysts, topazes, emeralds, and sapphires" found that on heating "Fluor Smaragdi" "in a pan of coals" and afterwards "putting it in a dark place (it) shines very much: At the same time several other stones were tried but did not shine." Monsieur Lort's

[1] "An Account of a Journey made through Part of the Low Countries, Germany, Italy, and France about 1663–5," "Churchill's Voyages," 1732, Vol. VI, p. 718.

notebooks would make interesting reading to-day. Some fluorspar, particularly the variety chlorophane, is so fluorescent that it becomes luminescent by the heat of one's hand. Gustave Rose, the great German mineralogist, during his travels in Russia is said to have seen among the gravels of the Irtish River, near Krasnojarsk, chlorophane pebbles which shone with brilliancy all night long, merely due to being subjected during the day to the sun's heat. The Reverend C. W. King believed that phosphorescence "must often have attracted the notice of Orientals on entering their gloomy chambers after exposure to their blazing sun and thus have afforded sufficient foundation to the wonderful tales built upon the simple fact by their luxuriant 'imaginations.'" I thoroughly agree that the Orientals must have noted the phenomenon as did undoubtedly many a savage striking quartz fragments together to get fire. While it is therefore not impossible that the inventors of certain of the tales may have been acquainted with the luminosity of gems, in my opinion many of the tales must be of other origin.

Perhaps, however, the discoverer of the luminescence of gem stones may have been an American Indian. In the kivas or shrines of the pueblos of our Southwest, the drum in certain religious ceremonials portrays thunder and in the darkness of the shrine two pieces of quartz rubbed against one another, lightning. A. V. Kidder in the ruins of the Pecos pueblo, San Miguel County, New Mexico, a pueblo long abandoned, found a "lightning stone," a cylinder of rock crystal which was made to revolve in a base with a shallow semi-circular groove, exactly fitting the cylinder. When the cylinder was rapidly revolved on its base, both elements became markedly luminous. Here we have a machine, a highly evolved mechanism, the joint product of the lapidary and the physicist, which we infer to be perhaps 700 years old. The discovery must be many centuries older, probably by an Indian making in some shaded spot an arrow from quartz.

The recital of the principal, and particularly the older, of the folk tales of luminous gems may not be without interest and will suggest whether these tales are of Greek, Roman, Chinese, Hindoo or medieval European origin. The loci of the stories is all Asia, except Siberia, all Europe except Norway and Russia, Borneo, New Guinea, the United States, Canada, certain South American countries and Abyssinia, French Congo and Angola in Africa. I think, however, the American and African myths were introduced by Europeans. The originators of the tales are Hindoos, Chinese, Hebrews, Greeks and Romans, and the European peoples, especially as to the latter, those of the Middle Ages. The earlier tales originated many centuries before the time of Christ and they are still being invented.

Most of the myths center around the carbuncle or ruby, stones not differentiated from one another by the classical and medieval mineralogists, less commonly around other gems, diamonds and pearls and still less commonly around olivine and onyx. Emerald, jade, cat's-eye and marble also appear as the subject of certain tales, as do certain stones which we can not identify, like "aster," "ceraunia," "hibien," "strange stones," the "sleeping stone" and the "stone that attracts stones." The earliest myths center around luminous precious stones (species unnamed), rubies and diamonds, but luminous emeralds, onyxes, pearls and jade have been described for over two thousand years. Strangely enough, fluorspar and certain species of amber, notably that from Sicily, while strongly fluorescent, do not figure in the myths, nor does opal, certain fine examples of which appear to be fairly alive with fire; indeed one fine example is known as the "Fire of Troy." Again lapis lazuli, used

widely as a decorative stone for over five thousand years, is not mentioned, although at least that from Chili phosphoresces when heated below red heat.

We have all, I think, likened the ruddy light of some fine ruby or garnet to a ball of fire, and the Greeks and Romans named them respectively "anthrax" and "carbunculus," each word meaning "glowing coal." Of course from the Greek form our word "anthracite" was derived. Mineralogists still call the beautiful deep-red garnet pyrope ("fire-eyed"). The Hebrew word for carbuncle is "Eqdach," from a root meaning "to light a fire." As to the other stones, perhaps the "fire" of the diamond may be an explanation, and Berthold Laufer notes that the Chinese apply the epithet "ye kuang" ("brilliant at night") to the diamond, an expression which he is inclined to believe originated in the fifth century of our era. Such an explanation can scarcely apply to the emerald and olivine, prized for their color and transparency, or to the pearl, jade, cat's-eye or marble.

Only in China and Japan and among the Jews and the Abyssinians is the pearl luminous. To these wise men of the East, the pearl is a product of the moon or in their mythology represents or is identical with it. Consequently, the night-shining legends of the pearl are logical, and even we to-day can see the similarity of a fine pearl and the full moon at its best. It may be added that after the luminescence of the Bologna stone (impure barite) was discovered by the Bolognese cobbler, Vincenzo Cascariolo, in 1602, it was sometimes called "lapis lunaris," as it gave out in the darkness the light it received from the sun. Imagination, however, was not lacking in the originator of folk-tales any more than in the creator of the latest detective story: scientific phenomenon to a small degree may have been the source of some few of the tales, mnemonic suggestion helped, but imagination predominated, particularly when we find a ruby or a garnet serving as a lighting plant for a large hall. In the Lei-chau peninsula, in Canton Province, famous throughout China for its myths as to thunder showers, after thunder showers "black stones are found emitting light and sonorous sound on being struck." That lightning and luminous stones are not more frequently associated seems strange.

The principal themes of the myths are three in number. First the illumination of buildings, a myth of Hindoo origin, although some of the stories may well have developed independently elsewhere. As variants, we have the lighting of ships, a myth of Hebrew origin and the guiding of lost persons first appearing in Europe in the Middle Ages. Second, we have the gem-mining stories, the gem being located at night due to its light-giving qualities and extracted by day, tales of Greek origin. The third, the serpent or animal theme, is of Hindoo origin: the variant in which the jewel is in the head of a small animal, the carbunculo, is probably a Spanish adaptation of the story and a further variant, that of the Grateful Beast, is probably independently of Chinese and Roman origin.

The writer has elsewhere expressed the belief that the fine gems, the diamond, ruby and sapphire, were first known to the Hindoos between 800 and 600 B.C. About this time appeared the Vishnu Purâna, in which it is stated that Vishnu, in his incarnation as Seshanâga under the name Ananta ("Endless"), "has a thousand heads adorned with the mystical Swâstika and in each head a jewel to give light." The Vedas also hold that the fixed stars have no actual existence, but that the objects which shine by night are couches of gold set with diamonds and rubies on which the inhabitants of paradise repose. The ancient Hindoo book, Mahabharata (perhaps 200 B.C. to 200 A.D.), tells in the story of the Pan-

davas brothers, of the palace of the raja Babhruváhana with its precious stones that "shóne like lamps so that there was no need for any other light in the assembly." In the Buddhacharita (about 100 A.D.) the city of Kapila so shone with the splendor of gems "that darkness like poverty could find no place." So that in India, the earliest country in which fine gems were known, the luminous character of gems was believed in some twenty-five hundred years ago.

Herodotus (approximately 484–420 B.C.) was the first European to describe luminous gems. Two great columns in the temple of Hercules at Tyre, one of gold, the other of smaragdos (green gems including emerald), the latter of which shone with great brilliancy at night, excite his admiration. The wily priests doubtless enclosed a lamp in hollow green glass, to mislead the credulous. "On Rivers" probably written by the grammarian, Parthenius, Vergil's tutor in Greek, in the first century before our era states that in the Sagaris River the "Aster" is found, "which flames in the dark hence called 'Ballen,' the King, by the Phrygians." Pliny in the first century of our era describes the chrysolampis, an eastern gem, "pale by day but of a fiery lustre by night."

The earliest Chinese reference to luminous gems is found in the biography of Li Sen, he who burned the Confucian literature (210 B.C.) under the Emperor Shi Hwang-ti, in which "moon-bright pearls" and a "night shining" jade disk are mentioned.

Talmudic legends (dating from, say, 400 to 600 A.D.) contain rather numerous references to luminous gems: for example, Abraham was so jealous of his wives, and they were not few, that he incarcerated them in a city of iron with walls so high that the poor women saw neither the sun, the moon nor the stars. He generously, however, provided a great bowl filled with jewels which lighted up the whole building.

The best documented of the illumination tales and a characteristic one is that of the luminous carbuncle or ruby of the King of Ceylon, first mentioned by Cosmas Indicopleustes in the sixth century and thereafter described by many travelers, the latest of the seventeenth century. The stone, as big as a pine cone, was in a temple situated on a hill, some state in the Buddha Tooth Temple near Anurajapura. "Its magical brilliance illumines the whole heaven. In the calm of a clear and cloudless night it can be seen by all, even at a distance of 10,000 li" (the equivalent of the old li is so variable that the distance might vary from 3½ to 3,500 miles), says the Chinese Buddhist pilgrim, Hūan Tsang. Others state at night it shines "like a torch"; that it "serves instead of a lamp at night"; that it has "the appearance of a glowing fire" or of that "of a great flame of fire." Due to its luminescence, according to one of these early Chinese travelers, it was called "The Red Palace Illuminator."

In the latter part of the fifteenth century, John Norton, an English alchemist, wrote a poem entitled the "Ordinal or a manual of the chemical art."[2] He proposed to erect over the Thames, at London, a gold bridge, to be lighted by carbuncles set on golden pinnacles, "A glorious thing for men to beholde."

A variant of the illumination theme is that of boats lighted by luminous gems. An old Talmudic legend states that Noah's Ark was illuminated by a carbuncle, and as it shone more brilliant by night than by day, it permitted Noah to tell even in the torrential rains of the flood night from day. According to the Chanson de Roland, dating from the twelfth century, the Saracen ships coming from Africa were lighted by carbuncles. Strangely enough, somewhat over a century ago the idea was incorporated in the Book of the Mormons, sixteen small stones, white and clear,

[2] Elias Ashmole Theatrum Chemicum Britannicum, London, 1652, p. 27.

being touched with the fingers of the Lord so that they might "shine forth in darkness." A stone being placed in either end of each vessel, the Jaredites for the 344 days of their voyage to America had "light continually."

The theme of luminous gems guiding mariners and others originated in Europe in the Middle Ages. The earliest is probably the Scandinavian saga of the Visby garnets. Visby, now but a shadow of the old Hanseatic trade emporium, lies on the island of Gotland, about 150 miles south by east of Stockholm. The ruins of the monastery-church of the Dominicans, St. Nicholas, still stand. In the heyday of Visby's magnificence, huge garnets formed the center of two rose windows on the west gable end of the church, overlooking the Baltic Sea. Sagas say the two gems shone at night as brightly as did the sun at noon and guided mariners safely to the port. The treasures of the Church of St. Nicholas, particularly the garnets, were of such inestimable value that they were guarded night and day by 24 soldiers, and death was meted out to those who approached the church after sundown. In 1361 Valdemar IV, the ambitious and unscrupulous king of Denmark, attacked the town and after a brave defense, it fell. His rich booty, including the sparkling jewels, which he tore from the rose windows, was placed on his own, the largest ship of his fleet. It was wrecked on one of the Karls Islands, and while the king himself was saved, the treasure sank. To-day, in times of calm, devout Gotland fishermen know that the unearthly rose light which wells up from the deeps of the Baltic is but the luminosity of their sacred jewels, now resting on the bottom of the sea.

The wedding ring of the Virgin Mary and Joseph, according to different accounts, set with an onyx or an amethyst or made of a single green jasper was said to have been brought from the Holy Land in 996 A.D. It was placed in the Church of Mustiola, Clusium (modern Chiusi), Italy, and in 1473 transferred to the Franciscan monastery in that city. One of the brothers, Wintherus, a crafty German, stole it. As he fled, night came on: he knelt before the ring, and on promising to return it, it emitted a great light by which he traveled to Perugia. The two cities fought valiantly for the possession of this sacred relic, but in 1486 the Vatican awarded it to Perugia, where it was placed in the Chapel of the Church of St. Lawrence. That matchless raconteur of Western stories, Jim Bridger (do you know his tale of the petrified forest with petrified birds in mid-air with the notes they sing also suspended in the air petrified?), brought the tale to America. A party of whites were so closely pursued by Indians that they perforce hid during the day. For three consecutive nights they traveled by the luminescence of a great diamond in the face of a neighboring mountain.

The mining theme is of Greek origin and was almost simultaneously told a few years before Christ's birth by Diodorus Siculius and by Strabo. The island, Ophiodes, in the Red Sea (present Zebirget) was so called as it was infested with snakes which Ptolemy Philadelphus exterminated so that its olivines, even today the finest in the world, could be mined. Olivine first appears in Egyptian jewelry in the eighteenth century dynasty so that the source was presumably known some 1,500 years before Diodorus's time. The mines were the personal monopoly of the Egyptian king and were worked under the watchful eyes of his representatives. Diodorus says: "All were forbidden to set foot upon that Place: and if any landed there, he was presently put to death by the Keeper of the island. These Keepers were few and lived a most miserable Life; and lest the Stones should be stolen and carry'd off there was not a Ship left

there: and if any by chance pass near these places (out of fear of the King) they sail away as far off as they can." As the island was a barren waste, the miners, provided the provision ships did not arrive, were "driven to the utmost desperation." "The topaz is a transparent stone sparkling with a golden lustre, which, however, is not easy to be distinguished in the day-time," according to Strabo, "on account of the brightness of the surrounding light, but at night the stones are visible to those who collect them." Diodorus more dramatically states the stone "shines bright and glorious in the darkest night and discovers itself at a great distance. The Keepers of the Island disperse themselves into several Places to search for this stone and whenever it appears they mark the Place with a great Vessel of largeness sufficient to cover the sparkling Stone: and then in the Day-time go to the place, cut out the Stone, and deliver it to those that are Artists in polishing of 'em.'" Strangely enough the "topaz" of the legend is in reality our olivine, a stone not luminescent, while the true topaz is. Pliny repeats the same tale about the Carchedonia, probably a garnet from near Carthage; "found they are twinckling against the moonlight and especially when it is in the full."

This tale may well have been told to travelers by astute Egyptian gem merchants anxious to enhance the value of their wares by exaggerating the dangers inherent to procuring the olivines. And yet, to-day, in the tungsten mining industry, the fluorescence of one of its principal ores, scheelite, the calcium tungstate, is turned to advantage at the Mill City mine of the Nevada-Massachusetts Company. Portable ultra-violet lamps for fluorescing scheelite are used underground in geological work and in sampling the ore. The scheelite usually fluoresces a light blue. Fluorescence is also used in testing the quantity of scheelite in the various mill products. The use of ultra-violet lamps in detecting the amount of willemite (zinc orthosilicate) in the ores and mill products at the New Jersey Zinc Company's mine, at Franklin, New Jersey, has been standard practice since 1906.

There is an old Banian legend, the date of which is unknown to me, that to Shuddery, one of the four sons of the first humans, Pourous and Parcoutee, the first diamond mine was disclosed at night by the admirable brightness of its stones; he believed it fire till he found it "wanted the heate." He and his sons "did afterwards travaile to the myne of diamonds . . . and stored themselves with them which ever since have been merchandize of deere estimation." In the Psysiologus written about 125 A.D. it is stated that the diamond is not to be found in the day but only at night.

In 632 A.D. it is stated that the jade of the rivers of Khutan, Chinese Turkestan, being discovered by its shining in the water at night, was procured at low waters by divers.

A curious adaptation of Strabo's story is given as to the gold of the land of Ishmael, east of Nineveh, in the travels of Rabbi Petachia of Ratisbon (1170–87 A.D.). There "the gold grows like herbs. In the night its brightness is seen when a mark is made with dust or lime. They then come in the morning and gather the herbs upon which the gold is found." Lastly in the middle of the sixteenth century, Benvenuto Cellini tells us that one Jacques Cola found a carbuncle in his vineyard by its shining at night.

That snakes carry either in their forehead or in their mouth a most potent jewel is an almost world-wide legend. The legend reached Europe at least by the time of Christ, but is presumably of Hindoo origin, India being the earliest source of fine gems and a country by no means short of snakes. It has been suggested the myth is connected with snake

worship, but perhaps either the reflection of light on the serpent's bead-like eye or the flame color of certain snakes' mouths may be the origin of the myth. In only a relative few of these legends is the stone luminous, this variant being known in India, Ceylon, ancient Greece, Armenia, and strangely enough among our own Cherokee Indians. The myth has affinities with the dragon, the carbunculo and many of the "animal-gratitude" legends.

The serpent has in his head a gem, probably a ruby, which has the brightness of a lamp according to the Hindoo work, Brhatsamhita of Varahamihira (505–587 A.D.). In one of Somadeva's stories (eleventh century), the hero's submarine wanderings in search of the silver-jeweled tree is lighted by the Mani or precious jewel from a snake's head. The fact that in the "Life of Apollonius Tyanceus," by Philostratus (A.D. 170–245), the Greek states that in India stones endowed with a peculiar luster and a wonderful virtue are taken from serpents' heads, suggests that the myth is an ancient one in India. The author naïvely adds that the stone in the ring of Gyges which permitted him to see invisible things was of this nature.

The Ceylonese to-day, and it is said even some Europeans resident in Ceylon, believe the Kantha jewel is found in the mouth of certain, but by no means all, cobras. It is highly luminous, and when the serpent wishes to find anything in the dark it disgorges the jewel and swallows it again when its object has been attained. To obtain this sovereign gem the snake must not be killed, for that would be bad luck, but one must throw upon the disgorged gem a mass of clay, a bag of ashes, a basket or a cloth. The poor confused snake, no longer seeing his gem, finally disconsolately leaves the locality and the gem may be recovered. The cobra dies of grief or commits suicide. Dr. H. Hensoldt states he saw at night a cobra contemplating such a stone: and that later one given him by a native turned out to be chlorophane. He concludes that the stone fluoresces like a female fire-fly (a delicacy from the cobra's view-point): and that this serves as a decoy for gallant male flies, thus scientifically explaining the myth of precious stones in snakes' heads! The myth reached Persia over a thousand years and in the tale of the Rose of Bakawali, the heroic prince plunged the forest into darkness by throwing a lump of clay on the gem and the miserable snake and a dragon, who carried the snake in its own mouth, knocked their heads against rocks and died.

The Coreans worship the epkuron-gi, a snake, the guardian of their penates, who when of venerable age carries on his forehead a glistening jewel "ya-kang-chin." The name is applied to any glittering stone, especially the diamond. According to Armenian legend the serpents of Mt. Ararat are ruled by a queen who destroys her enemies by a magic stone, the Hul, carried in her mouth. This "stone of light" "upon certain nights she tosses in the air, when it shines as the sun. Happy the man who shall catch the stone as it falls."

The Cherokee have a myth, a variant of the Horned Serpent legend so prominent in Iroquois mythology, that upon the head of the prince of rattlesnakes there glittered a gem of magic powers. This was stolen by a cunning warrior successfully encased in leather armor against a host of poisonous fangs. The stone was held in religious awe and was only brought forth on state occasions. The stone or a substitute, said to have been transparent, was once supposed to be in possession of several medicine men and was used in divination and in medicine. No living Cherokee now has such a stone. The legend, first told by Lieutenant Henry Timberlake, in 1765, suggests European influence.

In some legends largely of Chinese

origin, dragons replace snakes. The old Chinese author Li-Shi-chên describes "thunder-beads" dropped from the mouth of a divine dragon which light an entire house by night. An Emperor of China many centuries ago, according to a legend of the Dusuns, a Bornean tribe with certain Chinese affinities, heard of a carbuncle upon the summit of Kinabalu guarded by a dragon. He sent his three sons to get it, vowing that the successful one would be his successor. The youngest stole the stone, but the enraged dragon finally overtook the robbers and destroyed all the junks except the one on which the three princes escaped to China. The other Chinese survivors, having no means of reaching their homeland, intermarried with the Dusun women. A variant is the love story of Po Kong, a young Chinese, and the daughter of a Dusun chief, who, marrying against the chief's wishes, fled from his village. One night they saw on the summit of Kinabalu a strange intermittent light, as the guardian dragon alternately swallowed and spit out an enormous carbuncle. The young couple got two handfuls of mud with which, when the carbuncle was on the ground, they blinded the dragon. Po Kong seized the gem, wrapped it in his coat and there was instant darkness. Po Kong basely deserted his wife, leaped a deep chasm into which the pursuing dragon crashed, and settled in a Tempassuk district town and became the founder of a local line of chieftains. But of his first wife and the carbuncle nothing more is known. Friar Jordanus, who wrote about 1330, states that the dragons of India Tertia (Eastern African, south of Abyssinia?) have on their heads "the lustrous stones which we call carbuncles." In their ill-advised attempts to fly they crash into a river issuing from Paradise. After seventy days the people recover the carbuncle and take it to Prester John, the Emperor of the Ethiopians. Sir John Chardin, writing after his third visit to Persia in 1686, says the Egptian carbuncle was probably "only an Oriental Ruby of higher Colour than usual." The Persians call it "Iceb Chirac, the Flambeau of the Night because of the property and Quality it has of enlightening all things round it." . . . "They tell you that the Carbuncle was bred within the Head of a Dragon, a Griffin, or a Royal Eagle, which was found upon the Mountain of Caf."

Another variant of the snake story is that of the "carbunculo," apparently of medieval European origin and introduced into America by the Spaniards. In the Embassy of the Abyssinian Patriarch, Don John Bermudez, to John III of Portugal, written in 1565, an animal of the Upper Nile is described "which they call of the shadow because it hath a skinne on the head wherewith it covereth a very precious stone which they say it hath in her head." William Finch reports in about 1608 the same animal in Sierra Leone. "The Negros told us of a strange beast (which the interpreter called a carbuncle) oft seene yet only by night, having a stone in his forehead, incredibly shining and giving him light to feed, attentive to the least noyse, which he no sooner heareth, but he presently covereth the same with a filme or skinne given him as a naturall covering that his splendour betray him not." Shortly thereafter the story is transferred to America although the bearer in the earliest version is a snake. The Carib Indians (Charles de Rochefort, The History of the Caribby Islands . . . Rendered into English by John Davies, London, 1666, p. 15) have for a long time entertained their visitors with a tale of a huge snake living in an inaccessible hollow on the island of Dominica, West Indies. "On its head was a very sparkling stone, like a Carbuncle, of inestimable price: That it commonly veil'd that rich Jewel with a thin moving skin, like that of a man's eye-lid: but that when it went

to drink or sported himself in the midst of that deep bottom, he fully discover'd it, and that the rocks and all about receiv'd a wonderful lustre from the fire issuing out of that precious crown."

In the highlands of Peru and Bolivia near Lake Titicaca and to a less extent on the Peruvian coast and in the Montaña the Indians tell extraordinary stories of the carbuncolo. Some claim to have seen it as at night it slinks through the thickets; an animal the size of a fox with long black hair. If followed, the animal opens a flap in his forehead, disclosing a brilliant precious stone which blinds whoever tries to grasp it. The flap is then let down and the animal escapes. I think we all have been startled at night by the apparent luminescence of animals' eyes. Tshudi states the story antedates the Spanish conquest, that the early missionaries were told of it by wild Indians and that the early viceroys officially instructed the missionaries to spare no pains to obtain the jewel. According to A. F. Bandelier, the carbunculo is a species of cat and the jewel of blood-red color. He adds it is supposed to dwell in the high snows of the peak Sajama near Oruro and that it impedes access to the peak. Notwithstanding the reported age of the myth, I believe that it was introduced by the Conquerors particularly as the Peruvian Indians, while acquainted with many precious and decorative stones, had none that might suggest a luminous object. The existence of the tale among Indians as different as those of Peru and Guatemala is further evidence of the introduction of the story to Latin America by the Spaniards. It should be noted how closely these American versions follow the pattern of the European form.

One of the early groups of legends has as its theme animal gratitude. Luminous gems figure in a number of such tales, which probably originated in China and Rome independently some two thousand years ago.

The earliest of these stories known to me is told by the Chinese philosopher, Huai-man-tse, of the second century B.C. A year after the Marquis of Siu had cured a wounded snake, it returned with a luminous pearl in its mouth. It was an inch in diameter, white, and emitted a light as bright as that of the moon, lighting a room like a torch. The same story is told of the Emperor Ho-ti, the stone in this case being a carbuncle. Laufer cites from the Sou Shên ki the following tale: K'uo i Ts', on having restored to health a crane shot by an archer, released it. One night two cranes—a male and a female—appeared before his door, carrying in their beaks moon-bright pearls to reward him.

The earliest of the Roman forms (AElian) of this legend dates about 222 A.D. and is that of Heraclea, a worthy widow of Tarentum, Italy. She had cured a stork of a broken leg. A year thereafter the grateful bird, as Heraclea sat at the door of her cottage, dropped in her lap a jewel, probably a carbuncle. That night as she awoke she found her chamber flooded with light, the stone shining like a burning torch.

Matthew Paris in his chronicles, written about 1195 A.D., states Richard Coeur de Lion used to tell as a parable the following: a Venetian, Vitalis, was rescued from a horrible death by a ladder being let down into a pit into which he had fallen. A lion and a serpent trapped in the same pit used his ladder to escape, and later the lion in gratitude brought to Vitalis a goat he had killed and the snake a luminous jewel which he carried in his mouth. Later the two animals appeared as his witnesses in a lawsuit which he gained. As Richard is reported to have told the story after his return from the Crusades he may have heard it in the East, as a similar story, without, however, the stone being luminous, is said to occur in the Arabic work, Kalila wa

Dimna (about 800 A.D.), and the Sanskrit work, Katha-Sarit-Sagara, written by Soma Deva in the twelfth century.

John Gower, writing in the fourteenth century, versifies a similar tale. Bardus, a poor wood chopper, helped from a pit a man, Adrian by name, an ape and a serpent. The man proved ungrateful, but the ape piled up faggots for Bardus, and the snake brought him in his mouth a stone more bright than crystal.

In the introductory paragraphs the early investigators of luminescence have been cited, and in fairness we should praise those who first doubted the exaggerated statements which are the foundation of the above myths. The earliest of these was the Portuguese traveler to India and gem expert, Garcias ab Orta (1563), who, having been told by a jeweler of a luminous carbuncle, doubted its existence. Cleandro Arnobio (1602) had also heard of luminous rubies, but was equally skeptical of their existence. Other doubters were Laet (1647), Robert de Berquen (1661) and Pierre de Rosnel (1668). John Josselyn, Gentleman (New England's Rarities, London, 1672, p. 225–6), after describing a highly luminous stone found by an Indian in New England, correctly adds "But I take it to be but a story." Chardin in 1686 defines the luminous carbuncle as an "imaginary stone," and M. L. Dutens, 1778, adds with a French rapier stroke "such things are not believed to-day." The first to doubt the luminous qualities of the pearl is appropriately a Chinese, Sung Ying-sing, who in 1628 wrote "it is not true that there are pearls emitting light at the hour of the dusk or night."

Luminescence, a property of certain gems and other minerals and one to-day of some practical importance, may well have been observed in India many centuries ago. The myths regarding them, originating in different countries and locally believed even in our day, had their origin however in the main through fancied resemblance of the gems to fire or through symbolic affinities of certain gems to the moon.

THE SHAPE AND SIZE OF THE EARTH

By Dr. WILLIAM BOWIE
U. S. COAST AND GEODETIC SURVEY

THERE are three surfaces of the earth that are used by those who are dealing with problems of geology, geodesy and geophysics. The first, and the one with which we are most familiar, is the actual irregular terrain, high in some places and depressed in others. It is the surface with which we deal in our daily activities. In the matter of its configuration, as referred to the level of the sea, we find elevations as great as 29,000 feet in the Himalayan Mountains and depths of water of as much as 34,000 feet in the area to the east of the Philippine Islands.

The second surface is the geoid or the surface of the waters of the oceans and of imaginary narrow sea-level canals extending through the continental areas. This surface is not one for which a mathematical formula can be written. It deviates in a most irregular way from a simple mathematical figure. But the deviations are due to well-known causes, and to a certain extent they can be predicted. The surface of the oceans moves up and down as the tide-producing forces of the sun and moon operate. When we speak of the sea-level surface we have in mind its average position. This can be determined for any place on the coast by means of tidal observations and has already been done at many places in this and other countries. But there are other disturbances of sea level. The precise leveling results show that for our coasts the surface of the water of the Pacific Ocean is about one-half meter higher than that of the Atlantic Ocean and Gulf of Mexico. This difference is no doubt due partly to differences in the densities of the waters of the two oceans, partly to the effects of winds and partly to differences in average barometric pressures over the two areas. Accurate leveling across the Isthmus of Panama shows that the water of the Pacific is about seven tenths of a foot higher than the water of the Caribbean Sea. What the difference in level is for the waters to the west and east of South America is not known, for no accurate leveling has been extended across that continent. Leveling in Europe, however, indicates that there is some difference in the elevation between the Black and Mediterranean Seas to the south and the waters of the Atlantic and Arctic Oceans to the north and west. The leveling in the United States shows also that there is a slope of sea level towards the north. These deviations of the sea level from a truly level surface are small and must be due primarily to differences in water densities and in meteorological conditions.

The third surface is a mathematical one. It is designed to be a mean of the geoid or sea-level surface. It is in the form of an ellipsoid of revolution with its minor axis coinciding with the axis of rotation of the earth. The intersection of the plane of a meridian and the ellipsoid will be a perfect ellipse. It is the surface formed by turning the ellipse formed by any meridianal plane around its minor axis. This mathematical surface of the earth probably does not deviate more than one or two hundred meters from the actual sea-level surface at any point. The greatest deviations would be in areas occupied by great mountain masses and the deepest parts

of the oceans. The development of the science of geodesy made it possible to determine the dimensions of the ellipsoid, usually called the figure of the earth, with considerable accuracy.

During the dark ages most people considered the earth to be flat, but it is reasonably certain that the opinions of the Babylonians and Greek philosophers that the earth is round had not entirely passed into oblivion. When Columbus discovered the Western Hemisphere the notion that the earth is flat was discredited, but even then the idea of a round earth was not accepted by all. Even today there are cults that will not accept the idea of a spherical surface of the earth.

From the time of Columbus to that of Newton most learned men held to the spherical shape of the earth. Newton was of the opinion that the law of gravitation, which he discovered and propounded to the world, called for a shape of the earth's surface which would be an oblate ellipsoid. It required a longer radius at the equator than at the poles. Newton's announcement created a stir in scientific circles and a controversy that was only settled by the measurement of arcs of meridians in Lapland in high latitudes and in Peru at or near the Equator. It is evident that if the shape of the earth is that of an oblate ellipsoid, the length of a degree of latitude at the equator will be shorter than will be a degree nearer the poles. The measurements made in Lapland and Peru substantiated Newton's views. That epoch-making geodetic work was done by expeditions sent out by the French Academy of Sciences. It was begun in Peru in 1735 and in Lapland during the following year.

The proof of Newton's theory as to the shape of the earth led to the measurement of many other arcs of meridians. Each additional measured arc made it possible to determine with greater accuracy the figure of the earth. Among the famous men who have determined the figure of the earth may be mentioned Airy, Bessel, Clarke and Hayford. Their results have been extensively used in charting the oceans and mapping the island and continental areas and in scientific research.

In order to determine the figure of the earth, it is necessary to measure the distances between places on the earth's surface at which astronomical observations for latitude and longitude have been made. The distances are determined by triangulation. In the early days of the sciences of geodesy and astronomy it was difficult, and in fact impossible, to determine differences of longitude with the requisite degree of accuracy. In consequence the early figures were based on astronomical latitudes only. The difficulty with longitudes was overcome when wire telegraphy came into use shortly before the middle of the nineteenth century. By means of the telegraph the local times at two distant places could be compared and the difference in their longitude derived. Recently the determination of the longitude of a place with respect to a base station has been greatly facilitated and simplified by the use of radio time comparisons.

For many years astronomers have made observations on the stars from which their positions in the heavens can be predicted for any time in the near future. The star catalogues prepared by the astronomers are used by the geodesist in his determination of latitude and longitude, and these serve as control for the extension of great networks of arcs of triangulation.

According to Norlund, of Denmark, triangulation was first used by Tycho Brahe, the famous astronomer, in 1578 when connecting his observatory at Uranienborg with the church towers in

Copenhagen, Helsingfor, Lund and many other places. He also measured a base line to control the lengths of the sides of his triangles. This triangulation was of low accuracy, for it was done before the invention of the telescope.

The first triangulation that may be classed as of high accuracy was that of Picard in France, begun in 1669, for which he used instruments for measuring horizontal angles that had telescopes, spider threads and microscopes. From Picard's time to the present, great progress has been made in the development of instruments and methods used in this class of work.

Triangulation is based on the simple mathematical principle that one can compute the lengths of the two other triangle sides if the length of one side and the values of two of the angles are known. In actual practice all three angles of the triangles are measured, and only occasionally is the side of a triangle actually measured as a base since a computed side can be used as the known length of a succeeding triangle. The bases vary in length from five to fifteen miles, depending upon the terrain. The measuring is done with invar tapes or wires. The probable error of the length of a base is seldom greater than one part in one million, or about one sixteenth of an inch per mile. The error of a measured angle is seldom as great as one second of arc.

An arc of triangulation consists of a continuous chain of triangles. One side of the first triangle is used as the base of the second one, and in turn each triangle depends for the lengths of its sides on the length of a side of a preceding triangle. Bases are measured at intervals of from ten to twenty triangles, as a check on the accuracy.

In areas of high relief the theodolite, used for measuring the angles of the triangles, is supported by a low stand, but in terrain of low relief, steel or wooden towers must be used to elevate the instrument to such heights as will enable the observer to see the other stations that form the triangle. The objects sighted on are electric lamps placed over the stations as it has been found that observations made at night are more accurate than those made during daylight. Formerly, observations were made in daylight on heliotropes, which consist of mirrors illuminated by sunlight.

The longitude of each triangulation station may be computed on the adopted ellipsoid or figure of the earth. The ellipsoid used in this country is that of Clarke of 1866. At intervals of from six to ten triangles the astronomical longitude and azimuth at a triangulation station are observed in order to control the azimuths or directions of the triangulation lines. While a single astronomical station may serve as the initial station for a triangulation system, yet it is desirable to have many astronomical stations in order to fix the triangulation system in its most probable position on the surface of the earth. The triangulation net of this country has about 67,000 miles of connected arcs of triangulation and astronomical latitudes, longitudes and azimuths determined at many hundreds of the stations. It will be possible for a new and more accurate figure of the earth to be derived from this great mass of geodetic data. This is a task for the officials of the Coast and Geodetic Survey, and no doubt they will undertake this very important work as soon as additional funds and personnel are furnished them.

In deriving a new figure of the earth the mathematician uses the differences in the latitudes and longitudes of the triangulation stations as derived from the astronomical observations and as derived from the computations of the triangulation. If there were no irregularity in the actual surface of the earth and if

there were no horizontal irregularities in the distribution of mass of the earth, the differences of the astronomic and geodetic positions of the stations would be due solely to the accidental errors of the triangulation and astronomical measurements and to the deviation from the truth of the adopted figure of the earth used in making the geodetic computations. Under these conditions the dimensions of the ellipsoid derived for the area of some one country, such as that of the United States, should be about the same as those obtained from the data in other large areas.

Conditions are not so simple as those outlined in the preceding paragraph. The irregular surface of the earth has the effect of influencing the direction of the plumb line to which all astronomical observations are referred. For example, the plumb line will be deflected to the west at stations to the east and close to a mountain range. At stations on the coast of a continent the deflection will ordinarily be toward the land and away from the ocean. Even low ranges of hills deflect the plumb line from the direction that is normal to the ellipsoid. With good maps and charts one can compute and allow for the influence of the topography on the direction of gravity in determining the astronomical positions of triangulation stations.

The topography, as is well known, is the mass above sea-level and the deficiency of mass in the oceans and seas. But there is another disturbing influence. It is the compensation, within the outer shell of the earth, of the topography. Under the continents the density of the shell materials is less than normal, while under the oceans the shell matter is greater than normal. The normal densities are for the shell under the coastal planes. The shell of the earth within which the compensating excesses and deficiencies exist extends to a depth of about 60 miles below sea-level. The higher the elevation the greater is the deviation from normal density in the shell below. It has been found that the pressure exerted by any large portion of the shell on the 60-mile surface is practically the same as that for any other portion of the shell of the same horizontal extent. At least it is safe to assume that this is true, for many tests made in widely separated parts of the earth bear it out. The shell of the earth is in a state of approximate equilibrium, a condition that was termed "isostasy" by the great geologist, C. E. Dutton. Isostasy may be defined simply as equal pressure.

The isostatic condition of the earth must be taken into account if the best results are to be obtained in the derivation of the dimensions of the earth from astronomical and geodetic data. This was done by Hayford when he derived the dimensions of the earth from data in this country. This is why the International Geodetic Association considered Hayford's values the most accurate ones and adopted them as the international standard in 1924.

The dimensions of the International Ellipsoid of Reference, based on Hayford's work are:

Equatorial radius	$= a =$	6,378.388	kilometers
	$=$	3,963.34	statute miles
Polar radius	$= b =$	6,356.914	kilometers
	$=$	3,949.99	statute miles

Flattening $= f = \dfrac{a-b}{a} = \dfrac{1}{297}$ exactly.

It would seem that the dimensions of the earth derived from data secured in one continent should be the same as those obtained from data from any other continent, provided isostasy were taken into account in both areas. This is no doubt close to the truth, but it is quite certain that the distribution of compensating densities in the shell of the earth is somewhat irregular and that the compensation

is not always perfect. In consequence, the computed effect of the compensation on the astronomical determinations of latitude and longitude will be somewhat in error. But this error is small, and although the dimensions of the earth derived from data in different parts of the earth will not be the same, they will be very close together. They will agree much more closely than dimensions obtained without taking isostasy into account.

For research on the figure of the earth and to consider other branches of the science of geodesy there was formed many years ago the International Geodetic Association. At the time of the world war about thirty countries were adhering to that organization. The science of geodesy has to deal with problems that are world-wide and therefore co-operation of the workers of many countries must be facilitated. At present there is a new geodetic association, one of the branches of the International Union of Geodesy and Geophysics, to which about thirty-five countries are adhering. The union has been invited to hold its triennial convention in Washington, D. C., in September, 1939. The last convention of the union was held in Edinburgh, Scotland, in 1936. The American Geophysical Union, a branch of the National Research Council, is the organization of this country that deals with the international phases of the sciences of geodesy and geophysics and with the International Union.

THE HANCOCK PACIFIC EXPEDITIONS[1]

By Dr. HUBERT LYMAN CLARK

CURATOR OF MARINE INVERTEBRATES, MUSEUM OF COMPARATIVE ZOÖLOGY, HARVARD UNIVERSITY

THE recent gift of Captain Allan Hancock to the University of Southern California establishing the "Allan Hancock Foundation for Scientific Research" has attracted renewed attention to the work of the Hancock Expeditions of the past seven years. It is unfortunate that the scientific world has as yet little realized what these expeditions have accomplished or what the possibilities of the new foundation are. It is desirable therefore that a definite account of these expeditions should be presented to the readers of the SCIENTIFIC MONTHLY.

The present series of Hancock Pacific Expeditions began in 1931 and have been repeated each year, the seventh having just returned from San Juan Bay, Peru, the southernmost point as yet reached. The area which the expeditions have explored may be briefly designated as the eastern tropical Pacific. The American coast from Los Angeles to southern Peru has been extensively visited, and many outlying islands, notably Cocos and the Galapagos Archipelago, have served as bases for much biological collecting. While marine zoology has been the chief field of research, the land and fresh-water faunas of places seldom visited by scientists have not been neglected, nor has botanical research been ignored. From the start the work has been carried on in close coöperation with the zoological department of the University of Southern California, but on each expedition there have also been zoologists or botanists from other institutions, notably the United States National Museum. The remarkable success of the expeditions is undoubtedly due to the unusual spirit of coöperation inspired by Captain Hancock's wise leadership and the enthusiastic industry engendered by his constant consideration and generosity.

Naturally the vessel which has made the expeditions so successful is of prime interest in discussing them. For many years Captain Hancock has been an ardent navigator and a lover of the sea. Before the war, cruising in a small boat which he named the *Velero* (Spanish for "swift sailing") was a favorite occupation. The experience so derived led to the remodelling and enlarging of the boat, but even so, she was soon replaced by a larger vessel, the *Velero II*. But becoming convinced that a still larger boat, specially designed for long cruises such as scientists desired to make, was essential, Captain Hancock, with his chief officer, Mr. W. Chas. Swett, planned and supervised the building of his present cruiser, the *Velero III*. She was launched in the spring of 1931 and sailed on December 3rd of that year on the first of the Hancock Expeditions, to the Galapagos Islands and the western coast of tropical America. In the fall of 1927, Captain Hancock had visited the Galapagos Islands on a scientific cruise and it was due to the experience he gained thereby that the *Velero III* was so well adapted from the very first to her work in marine zoology and exploration. Although but 195 feet in length and having a net displacement of only 293 tons, she

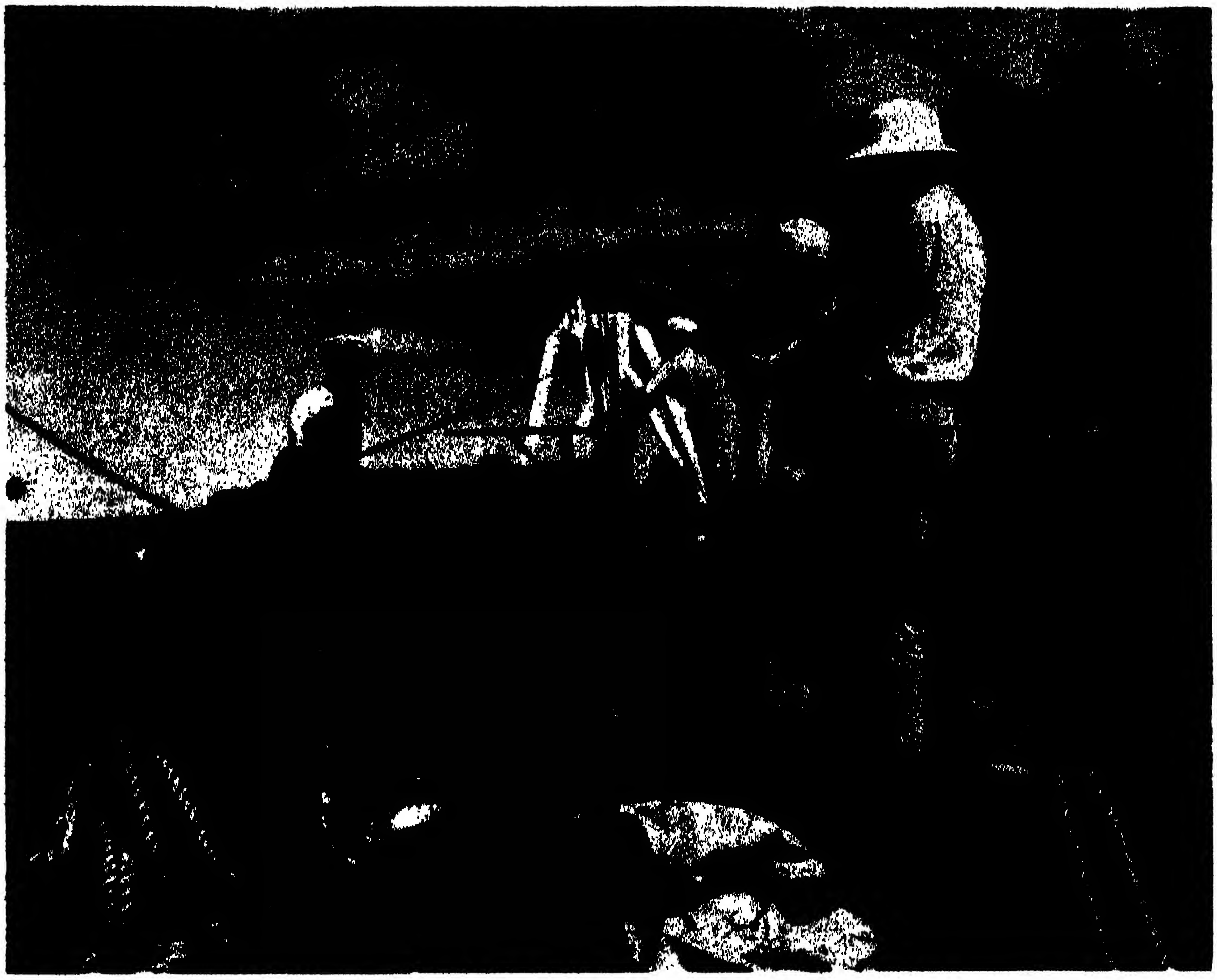
[1] Annual cruises of Hancock Expeditions have been made on the *Velero III*. The vessel was built in 1931 and fully equipped as a floating laboratory. Photographs are reproduced with this article through the courtesy of Captain Allan Hancock. They were taken by W. Chas. Swett, who has been a member of the expeditions since their inception.

rides the waves with wonderful steadiness, and has proved herself through seven years of service a most comfortable home, even for the landlubbers who comprise so large a part of the scientific staff. Her Diesel engines are powerful enough to enable her to cover nearly 300 miles a day, while all other operations for light, heat, ventilation, etc., are performed by electricity. The ventilating system is so nearly perfect that though the port-holes may not be opened during the whole cruise, the air in every room is as fresh and pure as that on the decks.

The equipment of the boat for work in marine zoology is complete, so that there need be no loss of time in either the collecting or caring for the material sought. Running salt and fresh water is always available and alcohol and other preservatives and reagents are amply provided. Seven years' experience has led to a perfection of detail in provision for the unexpected that is most unusual. Mr. John S. Garth, of the University of Southern California, has been on every voyage of the *Velero III* and has become an invaluable adviser and director of the scientific work. It is due in large measure to his unusual qualifications for the task that the work in marine zoology has been so successful.

The *Velero III* is now equipped with a large dredge and more than a thousand fathoms of wire cable so that collecting in deep water is possible, but most of the dredging is done from one of the five motor launches which the vessel carries,

THE *VELERO III*,
CAPTAIN ALLAN HANCOCK'S FLOATING SCIENTIFIC LABORATORY, AT ANCHOR OFF TROPICAL SHORES OF PORT UTRIA, COLOMBIA, SOUTH AMERICA.



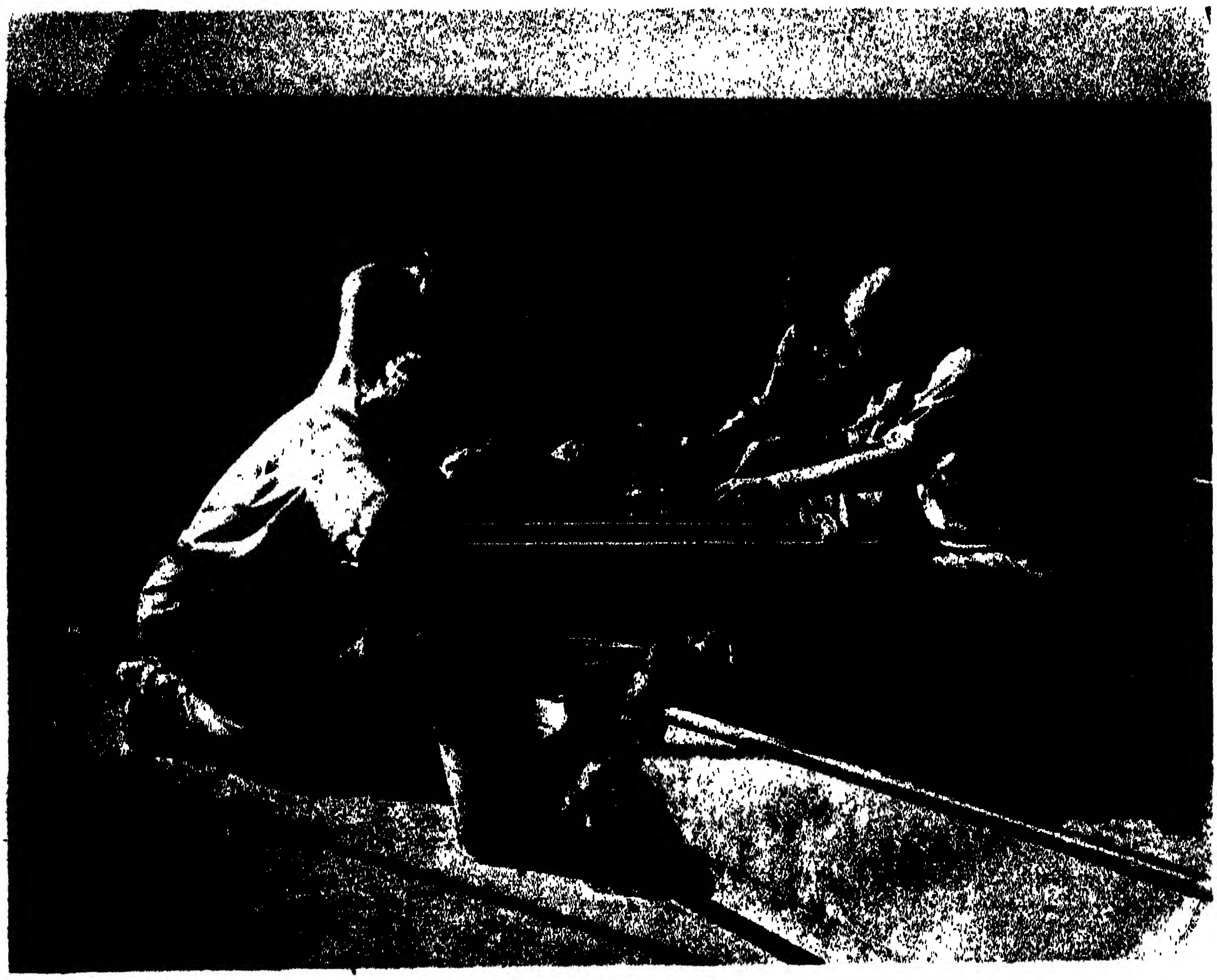
SPECIAL DEEP-SEA DREDGING GEAR

CAPABLE OF SAMPLING THE BOTTOM OF THE OCEAN AT DEPTHS OF A MILE OR MORE. A POWER WINCH REELING 7,000 FEET OF SPECIAL CABLE IS SHOWN WITH OPERATING CONTROLS.

at least two of which, plus two or three rowboats, are in constant use whenever the *Velero* is anchored. The dredging launch carries two hundred and fifty fathoms of wire cable, on a winch, which is directly connected with the engine, so that all handling of the dredge is done mechanically with rapid efficiency. Of course, there is also every facility provided for shore collecting either by dip nets or by hand, and there is ample equipment for exploration and all sorts of collecting on land. Nothing has been overlooked which can facilitate effective work in either zoology or botany.

The personnel of the expeditions has varied with each year, but for the most part has been sufficiently constant so that a real continuity runs through all seven expeditions. Captain Hancock has led them all, while the chief engineer and many members of the carefully chosen and highly efficient crew have always been along. The guests include an artist, a doctor (usually the genial and capable Dr. E. O. Palmer, of Hollywood, a long-time friend of the captain), and a photographer, but it should be added that the chief officer is a past grand master in the photographic art, as the accompanying illustrations amply testify, and most of the notable photographic work accomplished, both still and moving pictures, is the result of his skill. These remarkable films and photographs are available to all educational and research institutions which desire to make use of them.

The actual zoological work of the expeditions is closely tied up with two of

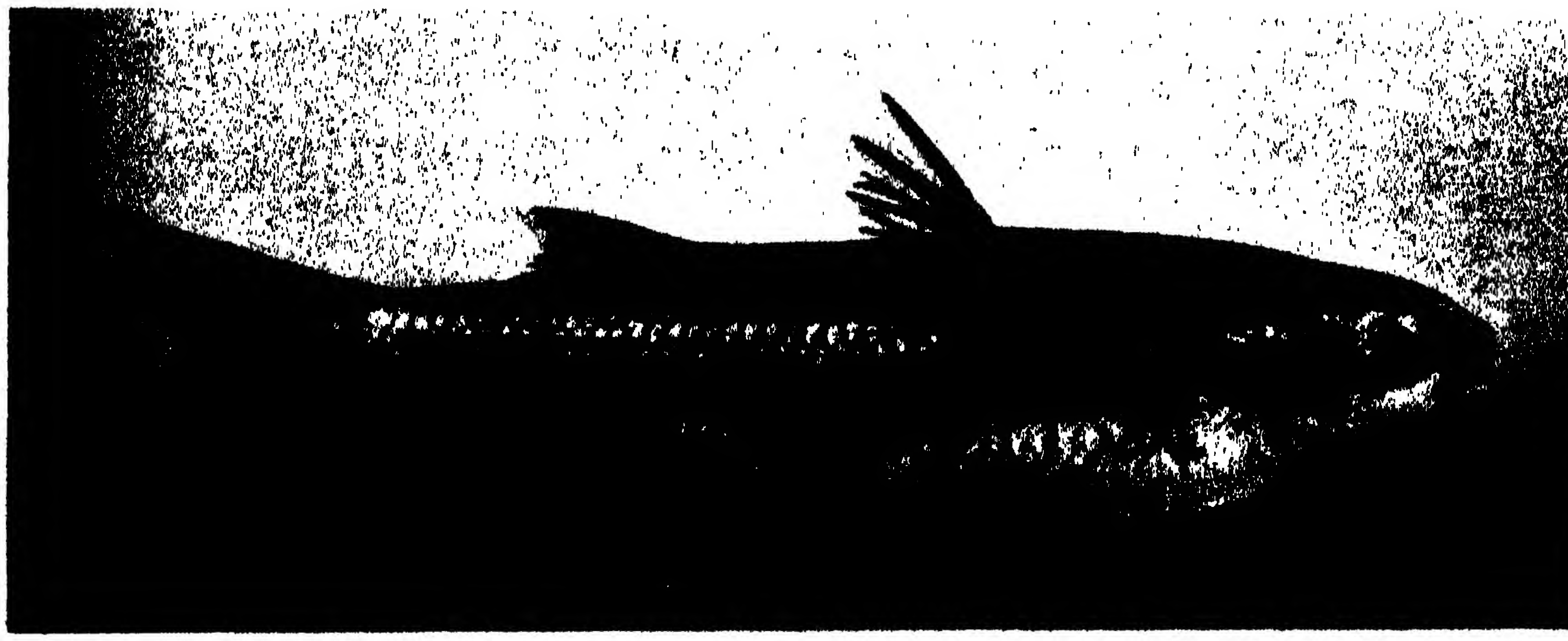


SCIENTISTS ABOARD THE *VELERO III*

EXAMINING A DEEP-SEA DREDGE HAUL ON SPECIAL PLATFORM LASHED ON BOW OF CRUISER. LEFT TO RIGHT, AROUND THE TABLE, ARE: DR. HUBERT LYMAN CLARK, HARVARD UNIVERSITY; ALEX HILL, UNIVERSITY OF SOUTHERN CALIFORNIA; JOHN S. GARTH, UNIVERSITY OF SOUTHERN CALIFORNIA, AND DR. GEORGE S. MYERS, STANFORD UNIVERSITY.

southern California's great institutions—the University of Southern California and the San Diego Zoological Park. One of Captain Hancock's notable traits is his great love for animals and his association with the San Diego Zoo is therefore most natural. As a member of the board of directors of that institution, he has its interest always in mind and generally one or more of its curators accompany the expeditions. But whether or not such a representative is aboard, the *Velero III* always brings back living animals for the Zoo. On the voyage just completed, the upper deck aft was crowded to the limit with the cages of more than a hundred living mammals, birds and reptiles. This interesting menagerie included a huge tortoise and many large iguanas from the Galapagos Islands, penguins, condors and vultures from Peru, pug-nosed seals from the same country, spectacled bears, marmosets and monkeys from Ecuador, and a big crocodile and a capybara from Panama. Captain Hancock's constant interest in and attention to these, his pets, assures them of the best care, and comfortable, even though restrained, freedom in their new and beautiful home.

The association of the University of Southern California with the zoological work of the expeditions has been close from the very start. Professor Irene McCulloch and her students have been constantly at Captain Hancock's service.

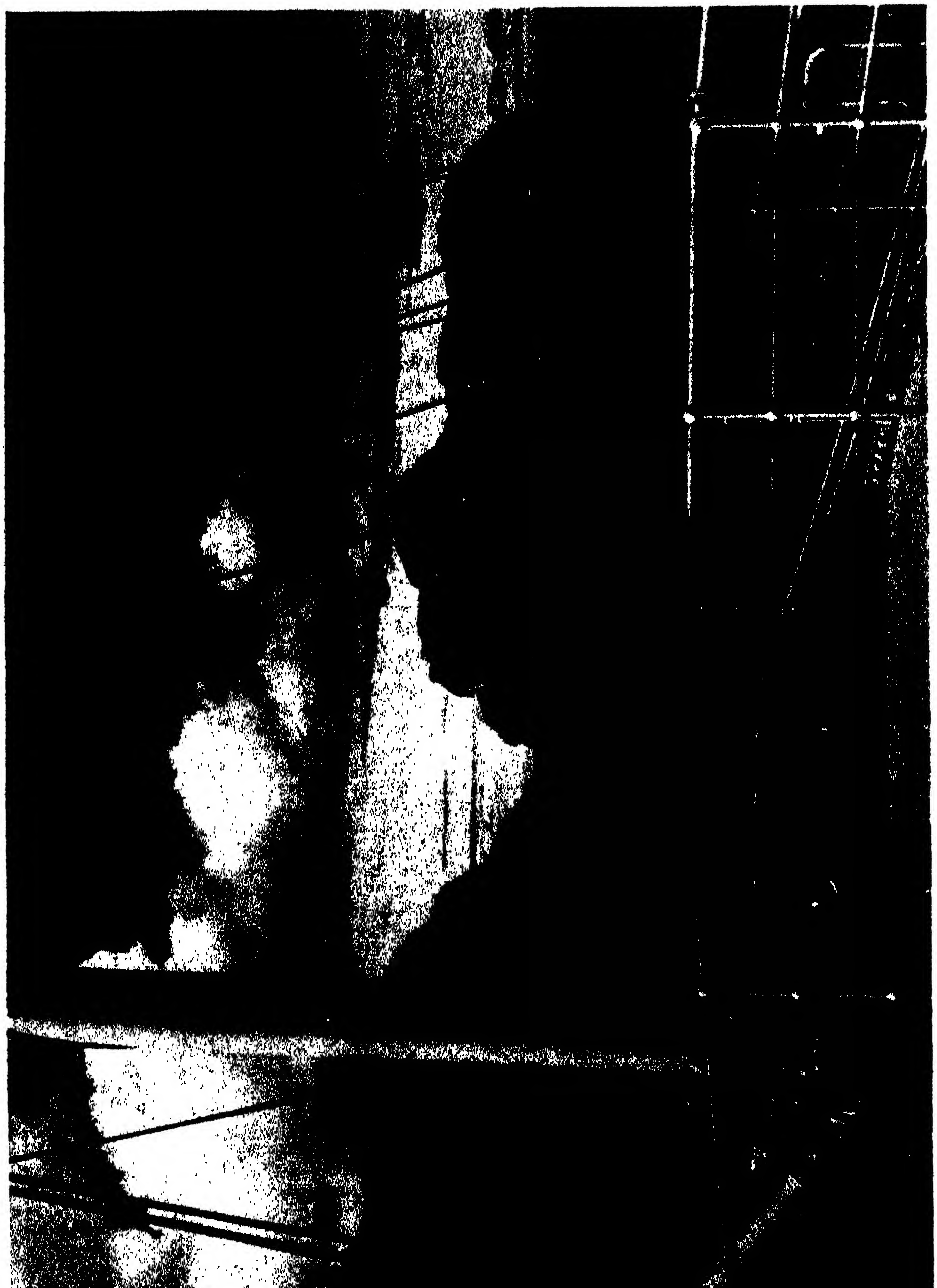


FRESH-WATER MULLET

CAPTURED IN A SPRING-FED STREAM ON CHATHAM ISLAND IN THE GALAPAGOS ARCHIPELAGO AND NAMED AGANOSTOMUS HANCOCKI SEALE, IN HONOR OF CAPTAIN ALLAN HANCOCK. ITS NEAREST RELATIVES ARE FRESH-WATER FISH OF THE CENTRAL AMERICAN MAINLAND.

A LARGE SPECIMEN OF THE FAMED LAND TORTOISE

FOR WHICH THE GALAPAGOS ISLANDS WERE NAMED, ON INDEFATIGABLE ISLAND IN THE EQUATORIAL ARCHIPELAGO. SEVERAL OF THIS SPECIES OBTAINED BY HANCOCK EXPEDITIONS HAVE BEEN PLACED IN THE SAN DIEGO ZOOLOGICAL GARDENS AT SAN DIEGO, CALIF.



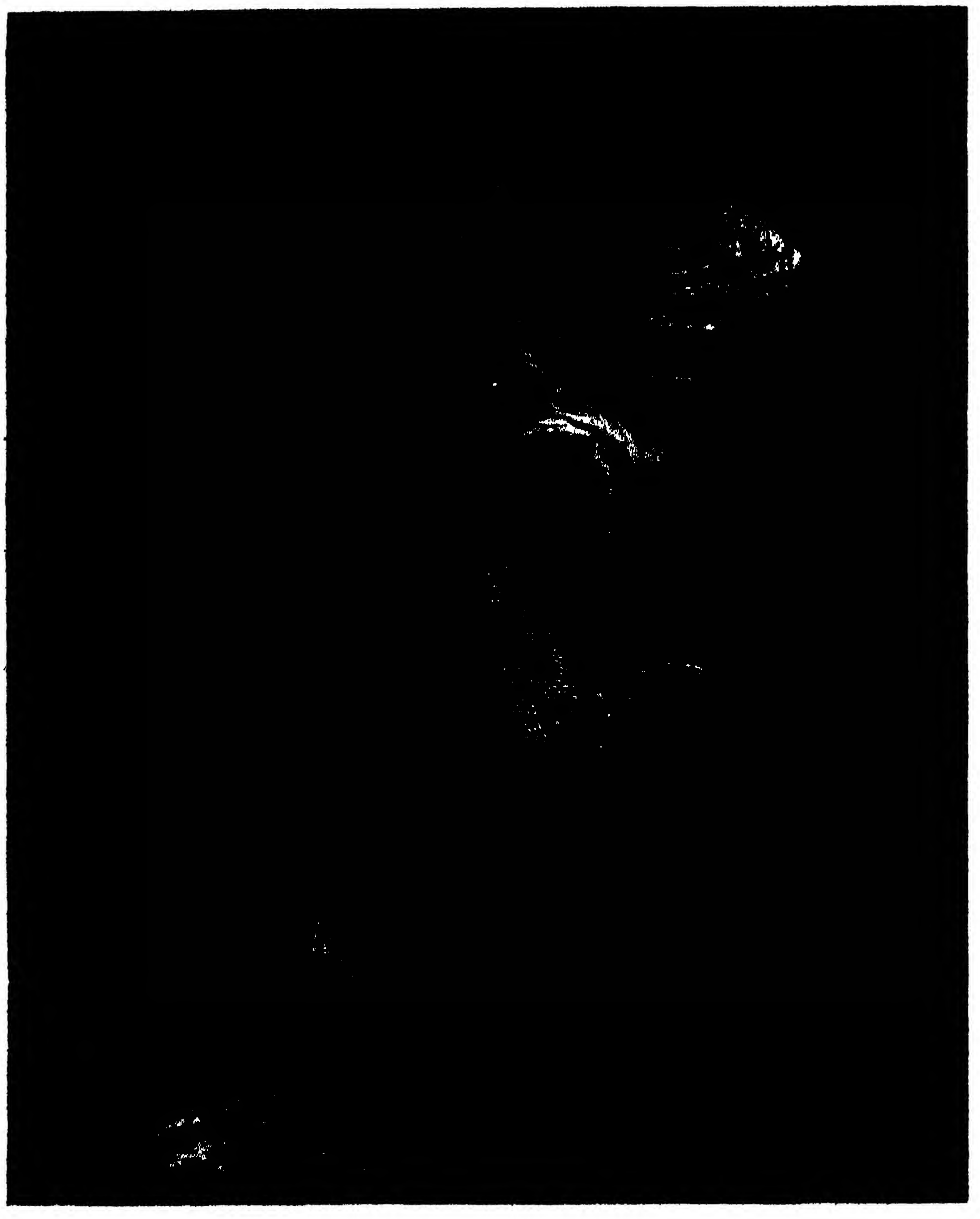
TROPICAL SHORES OF COCOS ISLAND,

OFF THE COAST OF COSTA RICA, LOOM ACROSS THE BOW OF CAPTAIN ALLAN HANCOCK'S EXPLORATION CRUISER, VELERO III. MANY VALUABLE SCIENTIFIC SPECIMENS WERE OBTAINED IN THIS REGION BY THE 1938 EXPEDITION.

Dr. McCulloch has supervised the storage and study of the collections as they come in from year to year, while at least two of her students, in addition to Mr. Garth, have accompanied each voyage. These young men, particularly Fred Ziesenhenne and Alex Hill, have become expert collectors of marine animals and past masters of the art of preparing and labeling such material. Moreover, students interested in birds and insects have made, on one occasion or another, important collections in those groups, which are now awaiting study in Los Angeles. On each voyage some older zoologist or botanist, or both, have been guests of Captain Hancock, and special effort has been made to give such men exceptional facilities for collecting and studying material in their special fields. These men have represented the United States National Museum, the University of Michigan, the University of British Columbia, Stanford University, the California Academy of Natural Sciences, the Steinhart Aquarium and the Museum of Comparative Zoölogy. They have had a wide range of interests and each has been most enthusiastically grateful for the privileges he has enjoyed.

The seven expeditions have covered a very large area in the eastern tropical Pacific, but those of 1936 and 1937 were devoted to the Gulf of California and the adjoining Mexican coasts. In 1934, the outlying islands of the Revillagigedo group, notably Socorro and Clarion, were visited and even the isolated Clipperton Island was given a brief examination, on the way to the Galapagos. The other four expeditions have explored the marine fauna of the Galapagos extensively, while by no means neglecting the land animals. All the islands, with the exception of Culpepper, which lies far off to the northwest, have been visited at least once, while Albemarle, Charles, Chatham, Indefatigable and James have each been visited five times. Cocos Island, one of the loveliest spots in the Pacific, has had three visits, and has proved to be the home of an abundant and remarkable marine fauna, with a number of apparently endemic species. On the South American coast, Ecuador has been visited three times, with a long enough stay at Guayaquil to permit inland visits to the Andes and once to Quito. The coast of Peru has been a collecting ground twice, with visits to Lima on each occasion. In 1935 the famous "bird islands" were visited, and in 1938, San Nicolas and San Juan Bays served as the base of several days collecting. Returning northward, Independencia Bay, with its interesting penguins, and half a dozen of the "bird islands" with their incredible flocks of sea-birds, gave an ornithological touch to the cruise. On all the expeditions, save those of 1936 and 1937, Balboa has been a port of call, with the possibility of visits to the famous Barro Colorado laboratory in Gatun Lake. Along the coast between Panama and Los Angeles much shore collecting and dredging has been done, at various well-chosen spots and great additions have been made to our knowledge of the fauna of that extended coast line.

The tangible results of the Hancock Expeditions are as yet chiefly visible in the laboratory of the zoological department of the University of Southern California, where a really marvelous collection of marine invertebrates has been built up. No effort is spared in making it possible for the *Velero III's* scientific staff to collect and preserve large series of specimens. As a consequence the collections now waiting critical study at Los Angeles are of extraordinary value, not only for the quality of their preservation, but for the long series from early youth to old age, making possible the investigation of many problems associated with growth and development. As yet publications based on this material are not numerous or extensive but nearly twenty reports, four of which are botanical, have been issued or are in press, while various other reports, some of which will be very extensive, are well



A FINE SPECIMEN OF LAND IGUANA

(CONOLOPHUS SUBCRISTATUS), PHOTOGRAPHED IN ITS NATURAL HABITAT ON SOUTH SEYMOUR ISLAND IN THE GALAPAGOS ARCHIPELAGO. MANY OF THESE SPECIMENS HAVE BEEN RETURNED BY HANCOCK EXPEDITIONS FOR EXHIBITION IN THE SAN DIEGO ZOOLOGICAL GARDENS AT SAN DIEGO, CALIF.

under way. With the new Hancock Foundation building, equipped and staffed, the progress of research on the great collections will receive new impetus. The intangible results of Captain Hancock's enthusiastic efforts to increase our knowledge of the life of the Eastern Pacific, along the coasts and among the islands of western tropical America, are less easy to formulate but are no less valuable. Obviously he has greatly stimulated interest in the work to be done and the problems to be solved. He is developing a group of young zoologists whose future work will be of great importance and he is providing the necessary facilities for the pursuit of their studies. By his unusual wisdom, unassuming but keen interest and able coöperation, he is creating and developing a center for biological research which will bring added renown to American science and be a permanent stimulus to the study of oceanic life.

SOME PHASES OF HUMAN RESPONSE IN THE FRENCH ALPS

By RAYMOND E. CRIST
UNIVERSITY OF ILLINOIS

Introduction

We live in an age of specialization and machine-made goods, yet many of the things we use are still made by hand, because mass production methods are not without their serious disadvantages in spite of their many advantages. The United States, with only 7 per cent. of the world's population, produces some 50 per cent. of the world's manufactured goods, yet Americans are not necessarily more ingenious than Europeans or Asiatics. Climatic, economic, psychological conditions—to mention only a few—are extremely favorable for mass production in the United States. For example, the cheap cotton glove sold in five and ten cent stores, for use generally by workmen, is a product that lends itself to mass production methods. There are several reasons for this: cotton products are cheap because cotton is grown and manufactured under almost optimum conditions in the South; the standard of living in the United States is relatively high; Americans are accustomed to buying new articles as soon as the old ones show the first signs of wear—whether it be a question of gloves or automobiles. It would be difficult, for instance, to sell a European a cheap automobile on the ground that it might be out of style or would begin to need repairs at the end of a year, so that he could simply trade it in for a new one; yet this kind of sales talk is an inducement to prospective buyers in America.

However, conditions are entirely different in the *kid* glove industry. There are three essential steps in the making of a kid glove: the preparation of the skin (removal of the hair and fleshy parts, tanning) dyeing (Fig. 1) and the final operations of cutting and sewing. Every skin is different in size, texture, defects, etc. No cutting machine can be made which will serve for thousands of skins, because each skin must be carefully evaluated as to size and number of gloves that can be cut from it. A defect in one corner, for example, would make it impossible to cut more than one large glove from the skin. Consequently this work, as well as such tasks as sorting, matching, sewing thumbs, etc., must be done by hand. Such an industry, therefore, must be located where labor is plentiful, and labor is often abundant in mountainous regions, where, as the population increases, the birthrate is checked, emigration is resorted to or industry is intensified. Often all three controls are operative simultaneously, yet, depending on certain variables, one may be more powerful than the others. In many of the mountainous areas of Europe, as the struggle with the harsh environment becomes more bitter, intensification of industry is resorted to by the inhabitants. To rather simple mountaineers, passionately attached to their soil, this might seem to be by far the easiest solution.

Chapareillan (Fig. 2), a peaceful little village in the broad Gresivaudan Valley, seemed to be a favored place for an intensive study of a family whose income was in part derived from household industry. Monsieur R. and his wife were kind enough to give detailed information as to the sources of the family income.

Household Industry

Madame R. sews gloves. She has specialized in sewing the fingers and

FIG. 1. A SMALL ESTABLISHMENT ON THE OUTSKIRTS OF GRENOBLE FOR THE DYEING OF KID SKINS

THE OWNER, A MASTER CRAFTSMAN, EMPLOYS ABOUT TEN WORKERS.

thumbs, while her neighbor sews in the ridges or patterns on the back of the gloves. Six months of apprenticeship are necessary before passable work can be done, two years before flawless work can be turned out. Madame R. tries to spend about eight hours a day four to six days a week at her work. In summer she works from five to eight or nine A.M., and from two or three to seven or eight P.M.—thus taking as much advantage as possible of daylight. The rest of the time she spends at her housework or in the kitchen garden. She can finish about two pairs an hour, at one franc fifty per pair. On an average she makes a minimum of two hundred and fifty francs a month.

Agricultural Activities

Monsieur R. is a gardener, who earns on the average about twenty-five francs a day for some twenty days a month. He boards at home, but is given all the wine he wants where he works—two or three liters a day in the summer time. On his own plot of six hundred square meters he raises potatoes, corn and beans, for home use, as well as feed for the hares. From ten to fifteen hares are kept on hand all the time (there were eleven in July, 1937). One is eaten every two or three weeks (fifteen to twenty a year). Meat of any kind is a luxury enjoyed usually not more than once a week. In addition to this small plot of rich valley land Monsieur R. has a vineyard of two thousand square meters, which is located at about a ten minutes' walk from his house. It is on a slope well exposed to the sun. In a good year the vineyard yields thirty hectoliters of wine, in a poor year not more than seven. A liter sells at from fifty centimes to one franc fifty—wholesale—depending on the year. He makes no money on the wine in poor years, since seven hundred liters are

necessary for home consumption, but he has made as much as two thousand francs from his vineyard in good years. Apple, fig, peach, cherry and walnut trees add their produce to the family larder.

Thus the total cash income is some nine or ten thousand francs—the equivalent of from three to five hundred dollars, depending on the purchasing power, which fluctuates constantly. This is not a great amount, but it is more than thousands of other families make. Furthermore, because of the self-sufficiency of the family along many lines, this is not so inadequate as it may at first seem.

Educational and Social Aspects

The only child in the family is a daughter, fourteen years old. She now attends a primary school, where a few higher courses are given. The nearest high school, or *lycée*, is at Chambery—15 kilometers away. If she should commute daily on the bus, it would cost five francs a day; to live there would cost three hundred francs a month, even if she came home Thursdays and Sundays. Thus the people in small villages are hard pressed to find the means of sending their children to high school. And besides, as her father said, "with a daughter, of all things, what can one do?" Her education would cost him twenty thousand francs, so he would rather save the money as he went along, lend it out at interest, and thus accumulate a dowry for her. What chance has this attractive, intelligent girl in the world? Very little at best. She will probably become a *gantière*, like her mother, and be the main support of her parents in their old age. Her dowry and her father's small holdings may make her desirable enough for some energetic young peasant to take

FIG. 2. CHAPAREILLAN ON THE NORTH SIDE OF THE BROAD VALLEY OF GRESIVAUDAN

THE SLOPES IN THE FOREGROUND, WHICH ARE WELL EXPOSED TO THE SUN, SUPPORT VINEYARDS, WHEREAS THE SHADED NORTHERN SLOPES ON THE OTHER SIDE OF THE VALLEY ARE LARGELY IN HAY OR PASTURE. THE LONG NARROW GRAIN FIELDS OCCUPY THE VALLEY FLOOR.

FIG. 3. SEWING GLOVES IN THE NARROW STREETS OF LA PALUD, JULY 14, 1937

FIG. 4. OLD IVY-COVERED HOUSE OF MONSIEUR R—— IN CHAPAREILLAN
A NEIGHBOR IS TAKING ADVANTAGE OF THE SHADE FOR HER SEWING.

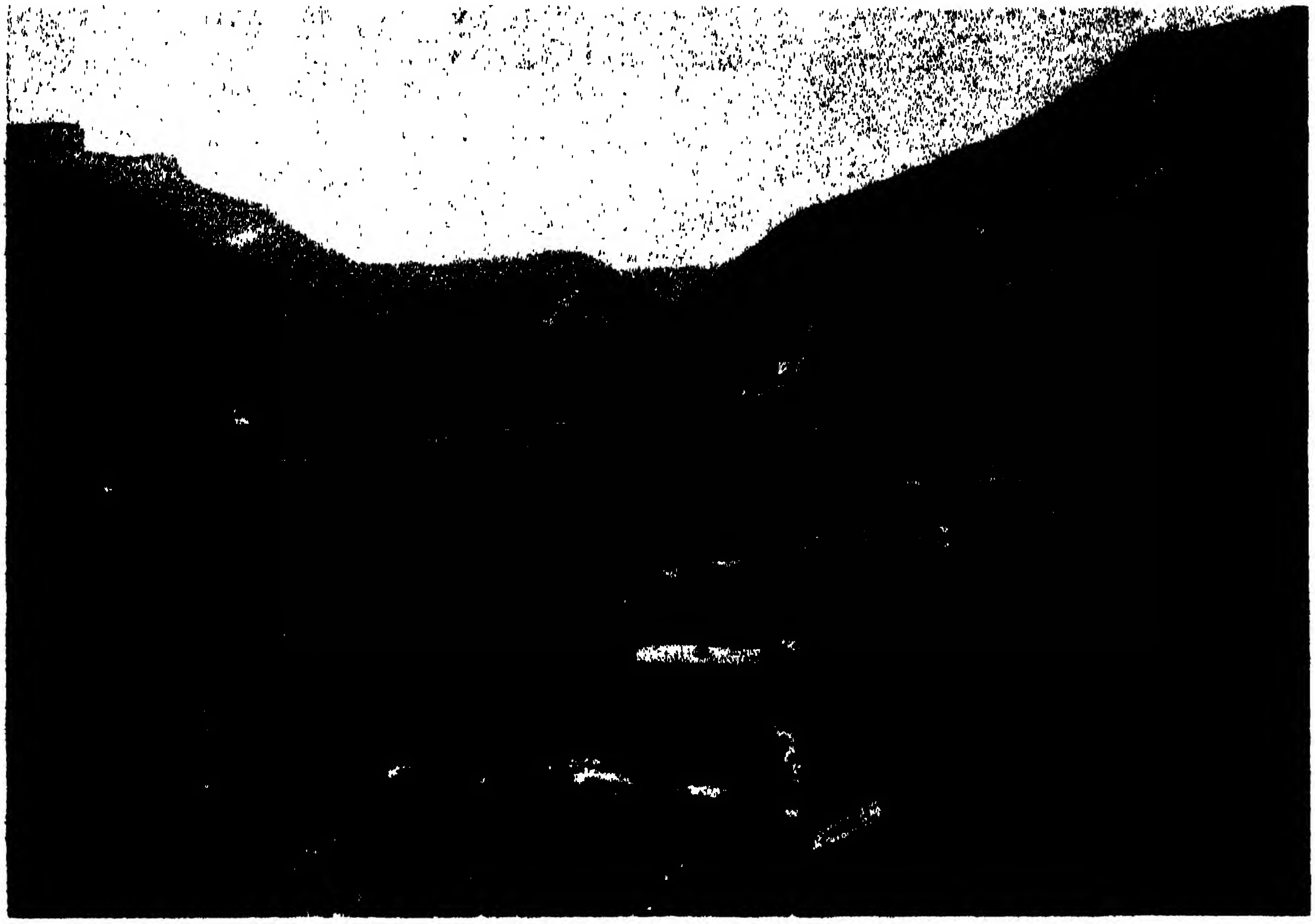


FIG. 5. THE SMALL RURAL VILLAGE OF NARBONNE

LOCATED IN THE CENTER OF A FERTILE MOUNTAIN TERRACE. THE PEASANTS WHO LIVE IN THIS VILLAGE, WHICH GREW UP AROUND A SMALL CHATEAU, ARE ENGAGED IN AGRICULTURE AND HOUSEHOLD CRAFTS. THERE IS NO STORE THERE, SO THEY DO ALL THEIR TRADING IN GRENOBLE. IT IS IN SUCH PEASANT VILLAGES THAT INDUSTRY OF THE HOUSEHOLD VARIETY IS MOST HIGHLY INTENSIFIED.

her in marriage. He will thus add some square meters of land to his own, and if he is lucky, his son will inherit the few acres and carry on the tradition.

Trends in Agriculture

Monsieur R. explained that a property worth five thousand francs may be made to keep a family of four or five members at the lowest level of subsistence, while a property valued at fifty to sixty thousand francs will bring in from ten to fifteen thousand francs. In a family of five children it is becoming almost necessary for three of them to seek work elsewhere. Even those left on the land may be forced to sell after a year or two of poor crops or of low prices because of bumper crops. With the introduction of machinery many workmen have left the countryside, and many vineyards have been abandoned altogether—particularly those which require all hand labor. Those who can survive on the land buy up the farms of those who must leave, thus large properties are taking the place of small ones.

Increase of Industry with Decrease in Soil Productivity

Chapareillan is just at the foot of the mountain, between the rich agricultural land of the valley and the poorer mountain slopes. It is noticeable that the making of gloves becomes more widespread as the productivity of the soil decreases. More people work at some phase of the glove industry in Chapareillan than on the rich valley floor, and as one continues up the mountain the industry increases in importance in the local economy. On July 14 the mountain ham-

let of La Palud was visited. It was a beautiful day; the sky was as blue as that along the Mediterranean, and the air was so clear that Mont Blanc was easily visible to the east. Whereas in even the smallest village in the valley very little work was being done, in this tiny hamlet there were seven women busy sewing gloves. They sat in front of their solidly constructed cottages (Fig. 3)—in which the live stock is also housed—sewing or knitting as they talked. In the narrow crooked streets were piles of tree branches to be used as firewood, great heaps of manure and an occasional worn-out farm tool. Chickens scratched nonchalantly in the streets. The request to take a picture was granted with a polite nod. Work was not stopped for a moment; it is expensive to work by artificial light, though so much of that is necessary in winter. The men were in the fields busy with the harvest; they could not afford to lose such a day in celebration, even on Bastille Day.

Conclusion

The conditions pictured in the foregoing paragraphs exist in many parts of Europe. Household industry seems so firmly anchored among the frugal hard-working people of the densely populated mountain areas that it would appear difficult for the inhabitants of more favored regions to compete with them. But only those articles that can pay their transportation costs to distant markets because of their relatively high value in proportion to weight or volume can be produced in these areas. Swiss watches and cheeses are good examples. Frequently, the people of one region will specialize in luxury goods which are almost wholly dependent upon foreign markets, and which may be among the first things foreigners will do without in the event of a depression. Unfortunately, such industries are often at the mercy of foreign legislators who have the power of erecting tariff walls. The French kid glove industry might easily suffer the same fate as the Swiss watch industry—which began as a household craft. Many Swiss watch-making establishments closed down permanently as a direct result of the United States Tariff Act of 1930. Men who had spent a lifetime acquiring the delicate skill required to engrave watch cases, or to make fine springs or screws were forced to lose this precious capital—perhaps irretrievably—by taking any work they could get—even day labor. Similarly, a tariff on kid gloves, behind which the workers of other countries could compete with the French, would disrupt the economy of a large part of the population of Grenoble and its environs. Thus twentieth-century man creates with one hand the best network of communications the world has yet known, yet with the other nullifies its effect by tariff walls which are as effective as barbed wire entanglements in stopping the flow of trade.

SCIENCE AND SOCIETY IN ANCIENT ROME

By Dr. WILLIAM SALANT

GUEST PROFESSOR OF PHARMACOLOGY, NEW YORK UNIVERSITY MEDICAL COLLEGE

THE economic interpretation of history and politics which is associated with the name of Marx has also been extended by his followers to the history of science. According to this view, of which Hessen[1] is the strongest living protagonist, the development of science is explained in terms of economics, by which is meant that the needs of mankind to provide for its existence furnish the stimulus to scientific investigation. Science is thus necessarily rooted in industry, agriculture and exchange of commodities. Hence a society which is distinguished for its practical achievements is regarded by some historians and sociologists as a necessarily favorable soil for the development of science. It is probably due to this assumption that led Bukharin,[2] the noted Marxian economist and sociologist, to speak, in one of his works, of Rome as one of the nations of antiquity that contributed so much to the progress of science. Substantially the same conclusion is implied in a recent address by Sigerist,[3] eminent as a historian of medicine and science, who stated that Alexandria and later Rome were centers of scientific research.

These statements contradict the conclusions of other recognized workers in this field. According to Sarton,[4] who is the foremost living historian of science, "Roman science at its best was but a pale imitation of the Greek." "The Romans," he continues, "were so afraid of disinterested research that they discouraged any investigation the utilitarian value of which was not obvious."

Reymond[5] remarked in his "History of Science" that the Romans were never distinguished for any love or even interest in pure science or abstract thinking. Virtually the same conclusion was reached by Heiberg,[6] and Fowler[7] made the interesting observation that even their literature and their philosophy had a practical object. They emphasized and extolled the moral qualities necessary for the preservation of the state and the increase of its power.

In the period of the Republic, as in the early centuries of the Empire, numerous and important enterprises were undertaken. The government built roads, canals, public edifices and aqueducts. There was also much activity and increased prosperity in industry, agriculture and commerce. It might be expected that a people with a practical turn of mind would devise new and better technical methods and elaborate improved processes, but historians of the economic life of ancient Rome have shown that there was a surprising paucity of inventions. They were not only few in number, but they lacked originality and were unimportant. To meet the demand for technical devices and improved methods which arose in the rapidly expanding Roman state, they availed themselves of those originated by the Greeks, Egyp-

[1] B. Hessen, "Science at the Cross Roads," Kniga Limited, London, 1931.

[2] N. Bukharin, "Historical Materialism," translated from the third Russian edition, International Pub., N. Y., 1925.

[3] Henry E. Sigerist, "Science and Society," II, 291, 1938.

[4] George Sarton, "The History of Science and the New Humanism," Harvard University Press, Cambridge, Mass., 1937.

[5] Arnold Reymond, Transl. by Ruth Gheury de Bray, E. P. Dutton and Company, New York.

[6] J. L. Heiberg, Transl. by D. C. Macgregor, Oxford University Press, London, 1922.

[7] W. Warde Fowler, Henry Holt and Company, New York.

tians, Phoenicians and those of other nations with whom they came in contact or conquered and enslaved. They were expert in appropriating ideas as well as property that did not belong to them. They borrowed much from the Etruscans. They copied their dress as well as their architecture and learned from them some of their arts and manufactures. They were indebted to them for the art of making trumpets, candelabra, pottery and other articles. The Phoenicians and Egyptians taught them glass-blowing. From the Egyptians they also acquired the knowledge of chemical processes they used in dyeing textiles. The Greeks were their teachers not only of literature, philosophy and other cultural subjects, but they also imparted to them the knowledge of technical methods as the art of weaving, metal-working, tool-making and other information of a practical value.

Romans, like many other people, as the Greeks, thus absorbed and profited much by their contacts with foreign nations, but the results were quite different. Whereas the knowledge and ideas appropriated by the Greeks served as stimuli to intellectual progress and led to discoveries in science and new conceptions of man and the world around him, this was not the case with the Romans and is well illustrated by the condition of technology and science in different periods of their history.

In the last two centuries of the Republic industry and commerce made much progress. According to Paul-Louis[8] and Rostovzev[9] the prosperity was indeed considerable, and as might be expected would be accompanied by the introduction of a number of technological improvements. Machines driven by air and water came into use in industry, as did other technical appliances, such as the continuous screw, the pulley, water-clocks. Indeed there was a fairly long list of various labor-saving devices. Other inventions also became known, even the uses of heat and improved chemical processes. Still further progress along the same lines was made in the first two centuries of the Empire, and a more systematic use was made of the science inherited from the school of Alexandria. Notwithstanding, however, the increased application of science and the greater use of invention, no discoveries were made and no new principles were developed. Indeed the magnificent Museum of Alexandria was the greatest and last effort of the ancient world to advance science on such an extensive scale.

Not long after the Romans began to impose their authority on the Greeks science began to decay. The battle of Cynocephalae was the beginning of Roman domination of Greek lands. It was also the beginning of the retrogression of science. The decline was not rapid, however, as tradition was too strong, but science began to languish and signs of degeneration gradually made their appearance. They could be noticed even in the work of the best minds. It was quite evident in the writing of Hipparchus, who was, according to Reymond, the greatest astronomer of antiquity. Yet he rejected the hypothesis of Aristarchus, who has been aptly called the Copernicus of antiquity. It is obvious that Hipparchus did not and could not escape the influence of his environment, which is generally described as the spirit of the times, which was notoriously reactionary and unfavorable, nay even hostile at times, to the development of new ideas. It can not be denied that there was still some scientific activity, but the results were meager and, with very few exceptions, lacked originality.

Mathematics continued to make some progress. Zenodorius, Hypsicles and Diocles—the three outstanding mathematicians of the period—carried on in-

[8] Paul-Louis, "Ancient Rome at Work," Alfred A. Knopf, 1927.

[9] M. I. Rostovzev, "The Social and Economic History of the Roman Empire," Oxford Clarendon Press, 1926.

vestigations along the lines laid down by Archimedes, Apollonius and Eudoxus and made important contributions.

Though some observations were still made in Alexandria, astronomical activity mainly consisted of texts which merely contained some of the knowledge gathered by previous workers. Worse still, superstition made inroads into astronomy and was corrupted, becoming a tool of astrology. According to Heiberg, even Hipparchus helped to spread this superstition.

Additional evidence of the decline of culture and the decay of science was furnished by the degradation of mineralogy to studies of the mystical properties of metals, although scientific works on metals had previously been published.

That other sciences shared in the downward trend was shown in geography. It was no longer concerned with the purely scientific aspect, but became entirely descriptive in the hands of Polybius, Agatharchides and others. The main object of geography, according to Polybius and Strabo, was practical—to be used by rulers and generals for their special purposes. Posidonius, who is regarded as the last scientific investigator of ancient Greece, was an exception, as he gave some attention to the scientific side of geography.

Particularly marked was the retrogression of zoology. The principal work on this subject was that by Alexander of Myndus, who lived in the first century B.C. It was a mixture consisting of extracts from Aristotle to which numerous fables were added.

It is of interest to note that zoology was not given any encouragement by agriculture or medicine, which probably accounts, at least in some measure, for its low and backward state.

Medicine also had deteriorated and had fallen from the level it reached in the days of Hippocrates and the Alexandrian period when considerable scientific investigation was carried on and the medical sciences, especially anatomy and physiology, made much progress, thanks to the labors of Herophilus, Erasistratus and their followers.

In the period under consideration mainly the practical side of medicine received attention. Asclepiades, who was one of the two most eminent physicians of the time, rejected the pathology as well as the physiology of Hippocrates and developed and founded a physiology based on the philosophy of Epicurus. The other physician of this period, who was a leader in medicine, was Heraclides of Tarentum, who wrote on the action of drugs and their uses. He belonged to the Empirical School which fought shy of theory and emphasized practical experiences. Due to the use of vegetable drugs, botany received some attention, as it was studied by physicians who were also apothecaries. It is evident that medicine fell in line with the sciences in their retrogression. Science was thus allowed to decay in Greek lands that were once part of the Alexandrian Empire. Their conquest by Rome ended the period of glorious achievement of science in Alexandria and other cities, where it flourished for centuries. Neither the government nor any member of the governing class was interested in the advancement of science, and no encouragement or support was given.

After a lapse of more than a century there was a revival of Greek science which accompanied the renaissance of Greek literature in the reign of Hadrian, and when the Antonines came into power scientific activity was considerable but, as will be shown presently, it was not distinguished by great originality and was frequently highly speculative. As in the preceding period, mathematics made the most progress. The leading men constituted a group whose achievements were quite noteworthy, Diophantus being the most eminent among them. He made original contributions, especially in algebra, which he called arithmetic, and dealt

with the solution of simple as well as quadratic and cubic equations. He also invented symbols for use in algebra. Until recently the work of Diophantus had been regarded by mathematicians, Ball[10] and others, as the earliest on the subject, but it is now known that, according to Smith,[11] the Babylonians were familiar with quadratics about 2000 B.C. As a reflection of the state of science of his time it is of interest to note that the work of Diophantus failed to attract the attention of his contemporaries. Not until his works were translated in the sixteenth century into Arabic did he get recognition for his contribution to mathematics, and later when Regiomontanus translated it in the fifteenth century into Latin Pappus, who lived at Alexandria in the latter part of the third century, was the second mathematician of note in this period. His work was the starting point of the analytical geometry of Descartes. Menelaus and Nichomacus, of the first and second centuries (A.D.), respectively also attempted original research in mathematics, but all the others were mere commentators. In astronomy Claudius Ptolemy was the dominating figure. His fame and influence rested for more than a thousand years on his erroneous conception that the earth is the center of the universe, the sun moving around it. He also rejected the hypothesis of the revolution of the earth around its axis. Under the influence of his fallacious theories and inaccurate observations the world remained long in ignorance of the true explanation of the movement of the heavenly bodies. He was also responsible for spreading superstition, as he devoted considerable space in his writings to astrology, in which he was a firm believer. He did not do much better in physics. In his optics he accepted the erroneous notions of Plato. However, he performed experiments of some importance on refraction and made observations on reflection with mirrors. Ptolemy imposed a considerable number of fallacies on his own and succeeding generations which persisted for more than a thousand years. And all this was accomplished in complete disregard of the great Aristarchus of Samos, whose remarkable discoveries and almost modern ideas antedated the writings of Ptolemy by nearly four centuries, which strongly emphasizes the decline of science in the Roman Empire. Hero of Alexandria may be included in this period, as he probably lived in the first or second century A.D. His writings were of a purely practical character. His work on mathematics was based largely on Euclid and Archimedes and did not contain anything original. Its main object was to aid in surveying. His principal contributions were in engineering and consisted of the invention of a leveling instrument, with books on vaults, throwing machines and works on mechanics which were derived from Archimedes. His books, especially those on pneumatics, show many defects indicating carelessness and little regard for experiment. Among the ideas he appropriated from others may also be mentioned the automatic theater, which originated with Philo. It should be added that his works have been of much value in throwing light on the state of science of his time and furnishing the best account of Greek mechanics.

Medicine in the Imperial period shared in the general decline of culture. The exhaustive account of Neuberger[12] shows that it was in a deplorable condition in the time of Galen. Owing to the lack of able thinkers and leaders capable of developing scientific methods, speculation dominated medical thought and whatever medical research there was at

[10] W. W. R. Ball, "A Short History of Mathematics," Macmillan and Company, London, 1901.

[11] David Eugene Smith, "Scripta Mathematica," IV, 111, 1936.

[12] M. Neuberger, "History of Medicine," transl. by Playfair, Oxford, 1910.

that time. The state of medical education was at a very low level. The medical sciences were taught in general educational institutions, and instruction consisted of didactic exercises only. Even anatomy was learned merely from books. There was no state supervision of medical education nor did the Roman rulers take any interest in it, until Alexander Severus, who was the first to appoint salaried teachers in medicine and to provide special lecture rooms. In the absence of control by the state charlatanry flourished, and Rome was full of quacks. Superstition in medicine was wide-spread in the Imperial era, and even the medical profession catered to the ignorant public by approving of various magical and superstitious rites as therapeutic measures without drawing much protest from the cultured class, which also believed in them. However, it should be noted that some of the Emperors of the first and second centuries did make an attempt to improve conditions in the practice of medicine. All forms of superstition and the beneficial effects of miracles had such a hold on the mind of the public that, according to Neuberger, Pausanias and Suetonius fell victims to it and even Pliny was not completely free from superstition.

Thanks to tradition, however, the Roman Empire could boast of a few medical men who, for their day, may be regarded as men of science and did make some contributions of value, as Themiso, the founder of the so-called Methodist School in Medicine, who lived in the first century A.D. Another member of this school was Soranus of Ephesus, who flourished in the second century A.D. He wrote on every branch of medicine and left also a creditable work on obstetrics and how to care for the new-born child.

Archigenes was the best representative of the Pneumatist School, which made careful studies of diet and investigated the effects of wine and mineral water. He also wrote on the effects of medicines, which we would now call pharmacology.

The most important figure of this period was Galen, who died in 200 A.D. His ideas on clinical medicine, pathology, the effects of drugs and on physiology prevailed for about 1,500 years. In fact, they dominated physiology and medicine. He dissected animals of all kinds, especially the anthropoids, and carried on experiments on live animals. His writings were voluminous and dealt with many branches of medicine and surgery. Therapeutics also received special attention. He has been regarded as the founder of experimental physiology and made valuable contributions, the most important being the demonstration that the arterial pulse is due to the action of the heart. He made observations on the movements of the heart and studied the movements of the blood, but failed to discover the circulation, though he came very close to it. He also carried out studies on the physiology of respiration and the functions of the nervous system, making numerous experiments on animals for this purpose. Notwithstanding his devotion to the experimental method in physiology, his work in anatomy and the clinical observations he made he did not escape the influence of his environment. *A priori* conceptions found a prominent place in his scientific endeavors and, of course, vitiated his results. He was given much to speculation and he greatly stressed design in nature. Theory was emphasized rather than, and at the expense of, unbiased observation. The induction and empirical observation so characteristic of Hippocrates and his followers received a subordinate place in Galen's scientific work, though he was not opposed to the teachings of Hippocrates. In some respects Galen even followed the great master and tried to restore Hippocrates's methods and ideas, but all his efforts were unsuccessful. The conditions and the spirit of the times were unfavorable and were incompatible with the freedom of thought and originality of Hippocrates and of his day.

The renaissance of the second century

A.D. in Rome was but an artificial imitation of ancient culture. Science and art lacked originality. Medicine did not and could not rise above the prevailing level of culture and assume an attitude of mind different from that which was characteristic of the time. If under Roman domination the Greeks, notwithstanding their tradition of the golden age of science, either lost the spirit of their ancestors or lacked the power or both to continue in their path what, may be asked, was the attitude of the Romans themselves toward science? The ruling class being Roman and in possession of wealth and tremendous power, what interest did they show in science? The answer was partly indicated above. It might be added that the Roman, whatever his class, had even less regard for science than the Greek idealist who followed in the footsteps of Plato. While Plato denounced experiment as a base art he at least regarded mathematics as a sublime study worthy of the attention of philosophers, which he exemplified by his own devotion to the subject. But not so the Romans. To quote Heiberg again, "they had always in their hearts that mixture of suspicion and contempt for pure science which is still the hall-mark of the half-educated." An illustration of the lack of esteem, even of the most cultured, for pure science were the utterances of Cicero. He spoke with approval of the Roman dislike of mathematics, except as it serves practical ends. To what extent they ignored the interests of science is well shown when the records of their scientific activity are examined, which were very scanty. Though much surveying and construction were carried on in the Roman Empire the mathematics used was translated from Greek texts and was reduced to mere rules that could be readily applied so that knowledge of theory and understanding of principle were not necessary. When surveying beyond the simplest type was needed, Greeks had to be employed, showing how little the Romans knew even of applied science. That no work of merit on mathematics was produced by Romans is well known. The same was true of astronomy. In the natural sciences Pliny was the outstanding figure, but his work was mere compilation and much of it was worthless.

Medicine did not fare much better. Cato advocated the use of panaceas and had no use for physicians. The only works of value were translations from Greek originals, as those by Celsius and later by Caelius Aurelianus, who rendered into Latin the works of Soranus.

Descriptive geography and ethnology received some attention at the hands of a few writers and statesmen. Cato, Sallust and Caesar made some contributions in these branches, but of scientific geography the Romans had little or no idea. They were centuries behind the ancient Greeks in this respect, as shown by the writings of Tacitus—in which it appeared that he did not know that the earth is round. The above account gives a good picture of the state of science in the Roman Empire.

As might be expected, superstition flourished under such circumstances. Astrology was highly regarded and was considered a science. It was popular with the cultured and even with men of letters.

Scientific work of any consequence among the Romans, as will have been noticed, was Greek in origin. The most important scientists who worked in ancient Rome were Greeks and wrote in their own language, while works of science in Latin were translations from Greek.

It has been maintained by a number of writers that science is due to curiosity and that its development is also stimulated by contacts, imitation and other factors. Merton[13] attaches much importance to the effects of what he terms

[13] R. K. Merton, SCIENTIFIC MONTHLY, p. 165, Feb., 1937.

interrelation as a catalyzer of scientific thought. Commerce and industry are stressed by others as conditions favorable or even necessary for the progress of science. The cultural level and spirit of the age are assigned by a not small number of historians and philosophers of science as the determining factors in the growth of science. Certainly some of the above conditions existed in ancient Rome.

The progress of science in Greece was associated with the development of trade and industry, but their expansion in Rome in the last two centuries B.C., under the Republic and during the following two centuries in the Empire, as we have seen failed to bring about a significant advance in scientific knowledge. Though there was some scientific activity the results were immeasurably inferior to those of Athens and Ionia centuries before. It was much below the level of Magna Grecia and Alexandria.

To explain the state of science in lands under Roman rule the history of economic, political and social changes must be taken into consideration. As in the case of other ancient peoples, agriculture and raising of cattle formed the chief means of their subsistence in their early history. They were then peace-loving and industrious farmers, but driven by necessity they later became aggressive and warlike. The need of more land became urgent early in their history, as the soil was poor and could not support them adequately nor provide them with the necessary materials for the manufacture of clothes and other necessities. They therefore attacked their neighbors and deprived them of their fields and their cattle. Due to their backwardness and the primitive methods of agriculture and since Campania, Etruria and Lucania were not able to supply enough food, the Romans also made war on Sicily, Africa and Egypt to obtain cereals which these lands raised in abundance. Conflicts multiplied, became prolonged and bloody. Later war was incessant and the effects it produced brought about profound changes in the economic and social history of ancient Rome, affecting the character as well as the culture of the Romans. The concentration of land in fewer hands which began in the fifth and fourth centuries B.C. steadily increased and was greatly accelerated by conquests. The nobility and the plutocracy invaded the public lands, as was especially the case at the end of the Samnite wars, and also appropriated (during the earlier conquests) the land assigned to the plebeians in the conquered territories. The great wars during the period of the Republic contributed in other ways towards the growth of large estates known as latifundia, which reached their full development in the first century before the Christian Era and continued to expand until they reached the size of veritable principalities by the end of the first century A.D. The enormous number of captives sold into slavery provided the latifundia with an abundant supply of cheap labor which enriched the very large owner and ruined the small farmer, thus eliminating the middle class from agriculture.

But conquest furnished yet easier ways of accumulation. The victorious generals returned with thousands of pounds of gold and silver, most of which they did not hand over to the government. This influx of wealth also served to enrich the commercial classes and in the days of Cicero made many millionaires with very large incomes. The huge fortunes which were thus acquired called for little or no effort and an idle parasitic class thus developed with a passion for extravagance and luxurious living which was truly pathological. Commerce and industry, as was stated above, had greatly expanded during this period, but the prosperity was largely due to the great demand for luxuries. With abundant money in circulation prices were, therefore, very high and profits enormous,

which led to speculation rather than to the development of constructive enterprise and increased production. With slave labor in abundance there was naturally no need of new and improved methods to make enterprise profitable. Only such appliances and processes were introduced which were absolutely necessary, as when the tasks could not be satisfactorily, or at all, performed by human hands. Those already in existence and inherited from the Greeks and others of previous ages sufficed for the very limited needs. Besides, a class bent largely on spending and ease could not be expected to, and in fact did not, possess the mental attitude which leads to invention and supports or encourages discovery. Moreover, the outlook on life under these conditions was not the same as in modern times, when those who control production and exchange invest their profits to expand their enterprise and improve methods to increase profits.

As might be expected, the methods of agriculture were scarcely, if at all, improved with thousands of slaves on a single latifundium. The Romans of the period of the Republic were centuries behind the Greeks and Egyptians in this respect. Their agricultural implements were made of bronze and were usually manufactured on the premises, and scythes were not even sharpened with stones as late as the first century B.C.

The backward condition of technology was not the only factor underlying the decadence and the retardation of scientific development. The wars, foreign and internal, absorbed the energy and destroyed large masses of men. The classes from which scientists and inventors are recruited suffered heavy losses and those who survived could not but be affected by the prevailing outlook of their class upon life with abnormal tastes and unhealthy extravagant mode of living, which alone unfits body and mind for any exertion, not to speak of productive scholarship.

Fowler pointed out that the very large number of men killed in the wars carried on during this period greatly deteriorated family life, divorce was common and the women became neurotic. The effect on their progeny must have been unfavorable and undoubtedly contributed to the mental, moral and physical deterioration of the Romans. We have, therefore, a number of factors all of which combined must be detrimental to science as indeed to every form of intellectual activity. Nor can it be too strongly emphasized that the freedom of the individual, not only of the slave, but even of the citizen, had always been restricted in the Roman world. The individual was at first subordinated to the welfare of the primitive family or clan and later to the interests of the state when he was tied to the army and thus deprived of freedom of action. The possibility of self-expression and development of his individuality—the very condition so essential for scientific progress and which contributes so much to the advancement of science and also philosophy were absent in the Roman world from its early history.

As was stated above, science during the period of the Empire too had not met with much encouragement, and only exceptionally did the Greeks and hardly ever the Romans themselves make some contribution. The reason must again be sought in the state of society. Economic and social conditions in this period had undergone a considerable, though gradual, change from that which prevailed in the latter centuries of the Republic. Many improvements were introduced not only in manufacture but even in agriculture. On the latifundia, according to Rostovzev, agriculture was carried on along capitalistic and scientific lines, displacing the primitive peasant economy. Pliny the elder is authority for the statement that the works of Varro, Cato and Columella were used in their efforts to improve agricultural methods. This is

particularly interesting in view of the fact that just at this time slavery began to decline, thus indicating its inhibitory effect on the progress of technology and the advancement of science which sometimes results from it, especially when science is in its formative stage. However, notwithstanding these gains, economic and technological, science in this period failed to profit substantially. Some activity there was, as shown by the work of a few men, but in the main, as pointed out above, science continued to show deterioration. Analysis of the state of society reveals that some of the factors believed to be inimical to the development of science during the latter centuries of the Republic persisted. The mode of living and the outlook of the ruling class had not changed. Extravagance and luxury were still characteristics of the wealthy and also of the high officials. Many forms of self-indulgence producing enervation and an abnormal state of mind were quite common in the higher social strata now as before. But above all due consideration should be given to the following factors which are of particular importance, as they help to explain the state of science under the Empire.

Though industry and commerce had greatly expanded, agriculture still retained its supremacy in economic life and the latifundia continued to increase in number and also in size. Indeed half of Africa was in the hands of six owners about the year 100 A.D. The effect of the Pax Romana and the suppression of piracy are important in this connection. No longer were the markets flooded with tens of thousands of captives. But the tremendous power and influence which the owners of the vast princely estates exerted on politics and in society would necessarily lead to some governmental action to remedy the shortage of cheap labor and prevent the impending ruin of the great estates. The government therefore established a new institution, the coloni, who were the precursors of the serfs of the middle ages and not much different from them. Under the new system of labor the individual was, by law, bound to the land. Neither he nor his family could be sold like chattel, but his personal freedom was nevertheless nil. The social effect was important, as this form of bondage made its inroads into the free citizenry and the impoverished middle class, thus abolishing the liberty of a class that was once free.

Nor was this the only change. A number of new factors had developed which profoundly and sometimes quite rapidly modified society. The decline of slavery, civil wars, barbarian invasion and, not the least important, the insecurity of existence which these caused, produced economic ruin. This was materially aggravated by the exactions of the treasury, which, as in our day, was so burdensome that it checked production and threatened the very existence of the state. All these led to the establishment of state factories, with rigid control of production and exchange. Associations were created by the government which were charged with the duty of production and distribution. These corporations abolished initiative and, in ways innumerable, hampered and destroyed the freedom and initiative of the individual. Nor were these restrictions limited to the laborer. The possessors of wealth were also affected. It was a totalitarian state where all were subjected to its authority. As in fascist states to-day, freedom of the individual was extinct for the citizen, rich or poor. Science could not prosper under these conditions, as it received no recognition and little or no opportunity to develop, material and moral support were wanting. The attitude of mind induced in such an atmosphere, being wholly antagonistic to innovation, development of curiosity and creativeness, inevitably led to intellectual stagnation and hence to the decline of science.

The close relationship which has been shown to exist between the development

of science and socio-economic conditions naturally prompts the question why science made such strides in some Greek states. What was there in Ionia, Athens and Alexandria and Magna Grecia that made science possible?

Greek, like Roman, society was based on slavery, and agriculture was the main occupation of the Greeks. Commerce and industry were highly developed in the Greek state, but, as we have shown, these also reached respectable proportions in Ancient Rome. Class conflicts resulting in civil war and foreign wars also were common to both. Analysis shows, however, that notwithstanding their similarities the societies of Greece and Rome differed radically in many respects. In Ionia, Attica and the islands of Greece there were no large estates or latifundia. According to Glotz[14] in the fourth century B.C. in Attica an estate of forty-five acres was not considered small, while those who owned about sixty-four acres were counted among the rich landlords. This was also the case in Asia Minor and the islands. The love and respect the Greeks had for work is shown in many ways. All the landlords, even the rich, worked the land with their own hands, in striking contrast to the Roman owners of the latifundia. Slaves were, of course, employed, but mainly as domestics. Greek farmers used much skill and ingenuity, as they had to in order to improve the land, for the soil was very poor, which explains why slaves were employed so little in agriculture. As Xenophon said, the Greek farmer had to keep his eyes open and ask questions. In other words, he was compelled by the nature of his existence to observe and think, which thus made the Greeks such keen observers and alert mentally. Attica was poor in raw materials for use in manufacture and had few agricultural products. Hence trade was important and, the roads being bad, maritime commerce was necessarily developed and shipping made tremendous progress from the fifth century B.C. on. Hence Athens became supreme in commerce, and industry was greatly stimulated.

In the fourth and fifth centuries B.C. industry became so important economically and was so highly esteemed by the citizen, even by some philosophers, like Socrates, that craftsmen acquired political power. There were masons, shoemakers and other workers in the Athenian Assembly. Though the nobility and philosophers, like Plato and Aristotle, had contempt for every form of manual labor, citizens and even their daughters engaged in industry and trade. It was a disgrace to do nothing to escape poverty, said Pericles. Craftsmen, as artists, were honored, and commercial careers were not despised, even by intellectuals who preferred the liberal professions. In this connection it is worthy of mention that the sons of craftsmen and merchants entered the professions and took up intellectual and literary occupations. Socrates was the son of a stone mason. The father of Sophocles was a blacksmith, and Demosthenes was the son of an armorer. Though slaves were largely or in some cases almost entirely employed in industry much technical progress was made. Also slaves in Attica received protection against abuse and were considered human beings in the eyes of the government. Slaves were not as cheap as later in Rome, which may account for the progress of technology and the better treatment. That society in Athens and other progressive cities of Greece was different from that in Rome and the territories it ruled is shown by their different modes of living and hence their outlook on life. The Greek citizen of Attica, as in Ionia, was abstemious, frugal, worked in the fields, shops and at other tasks too numerous to mention. In addition he sailed the seas in search of trade or to explore and settle in distant countries where better

[14] Gustave Glotz, "Ancient Greece at Work," Alfred A. Knopf, New York, 1926.

opportunities awaited him. His mind was thus sharpened, his ambition aroused, and his imagination stimulated and his outlook broadened. This spirit of adventure naturally affected also the superior mind, but the reaction was different and manifested itself in the quest for new knowledge and led to the development of new ideas.

Science and philosophy, inseparable from it in that age, became the chief occupation, and the only one in some cases, for a small class, while some individuals divided their time between learning and business. However, commerce and industry do not always lead to intellectual development and to the progress of science. Corinth, according to Jardé,[15] was a great commercial and cosmopolitan city. It was known for its commerce and industry far and wide. It had built many ships for its trade with distant countries and had a powerful navy. Nowhere was manual labor more or even as much respected and honored. Wealth in land was unknown and there were no great landlords there. This, as will be seen, is a great advantage for science. Yet Corinth produced no science, though it was sufficiently advanced to use machines in some of its enterprises, especially for transport. The reason can only be guessed. The commercial spirit was so predominant that, like war among Romans, it probably absorbed the energy of the ruling and wealthier classes who had leisure. And it is also worth mentioning, Corinth was a great pleasure-loving city. As the upper class could not have been large, it is within the bounds of possibility that the pursuit of wealth and pleasure also affected unfavorably the still smaller group of the more gifted among them. They probably could not emancipate themselves from the prevailing attitude of mind of the ruling class. Hence, as Clark[16] maintained, it is not a single factor which may be held exclusively responsible for the state of science. While a commercial and industrial nation may and often has produced men of science, this is not always and not necessarily the case. However, there is little doubt that some forms of society are unquestionably unfavorable, if not always antagonistic, to the progress of science. A country predominantly agricultural, with a rich and powerful landed aristocracy, has always been static in character and thus hostile to new ideas. This was the case in ancient Rome, in Sparta, Thessaly and other Greek states which were ruled by landed nobility. The feudal barons of the middle ages were no better. As Kofoid[17] pointed out in a recent article, science worthy of the name scarcely existed in the South before slavery was abolished. Society then determines the growth or the decline of science. It was no accident that the rise of Greek science followed the disintegration of primitive communism and the patriarchal family. Individualism and private property came into existence and permitted the unfolding of individuality. Likewise in the Renaissance science once more came to life and was destined to be raised to an infinitely higher level. The dissolution of the feudal system and the rise of the city bourgeoisie explain the age of discovery and the rebirth of science.

This study thus is in harmony with the conclusions of Levy[18], Hogben[19] and others, according to whom science has its roots in society. However, when some writers maintain that the economic factor alone accounts for existence and progress of science, this is an over-simplification and leads to erroneous conclusions. A number of conditions seem to coöperate in producing effects on science, beneficial or otherwise.

[15] A. Jardé, "The Formation of the Greek People," Alfred A. Knopf, New York, 1926.

[16] G. N. Clark, "Science and Social Welfare in the Age of Newton," Oxford Clarendon Press, 1937.

[17] Chas. A. Kofoid, *Science*, 88: 109, 1938.

[18] H. Levy, "Universe of Science," The Century Company, New York, 1933.

[19] Lancelot Hogben, *Science and Society*, 1: 137, 1937.

AGE AND HIGHWAY ACCIDENTS

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It will be the purpose of this paper to study the effect of age on highway accidents in the light of available facts. Since little is known or done about elderly users of the highway, special attention will be given to the effect of the aging process on driving.

More than a quarter of the population in the United States is over 40 years of age, and this proportion is steadily increasing. On the other hand, safety education is only now being seriously introduced into our public school system. Accordingly it will be years before present-day safety-minded children will replace our less safety-minded adults and improve the accident situation. In the meantime, our unselected drivers who were trained on 30-mile per hour cars will have to be retrained to drive their improved vehicles safely at the higher rates of speed prevailing on our highways.

All but five states license drivers. Only about half of them, however, require a road test examination. But even in our progressive states the selective measures to license drivers have had little effect on our adult driving population. The simple reason is that most state license laws were put into effect recently (Fig. 1) and all persons then operating motor vehicles were exempted from examination. Hence a considerable portion of our adult driver population has never had its ability or right to drive questioned.

Another fact commonly ignored is that many of our elderly motorists learned to drive relatively late in life when their habits were rather inflexible. Elderly

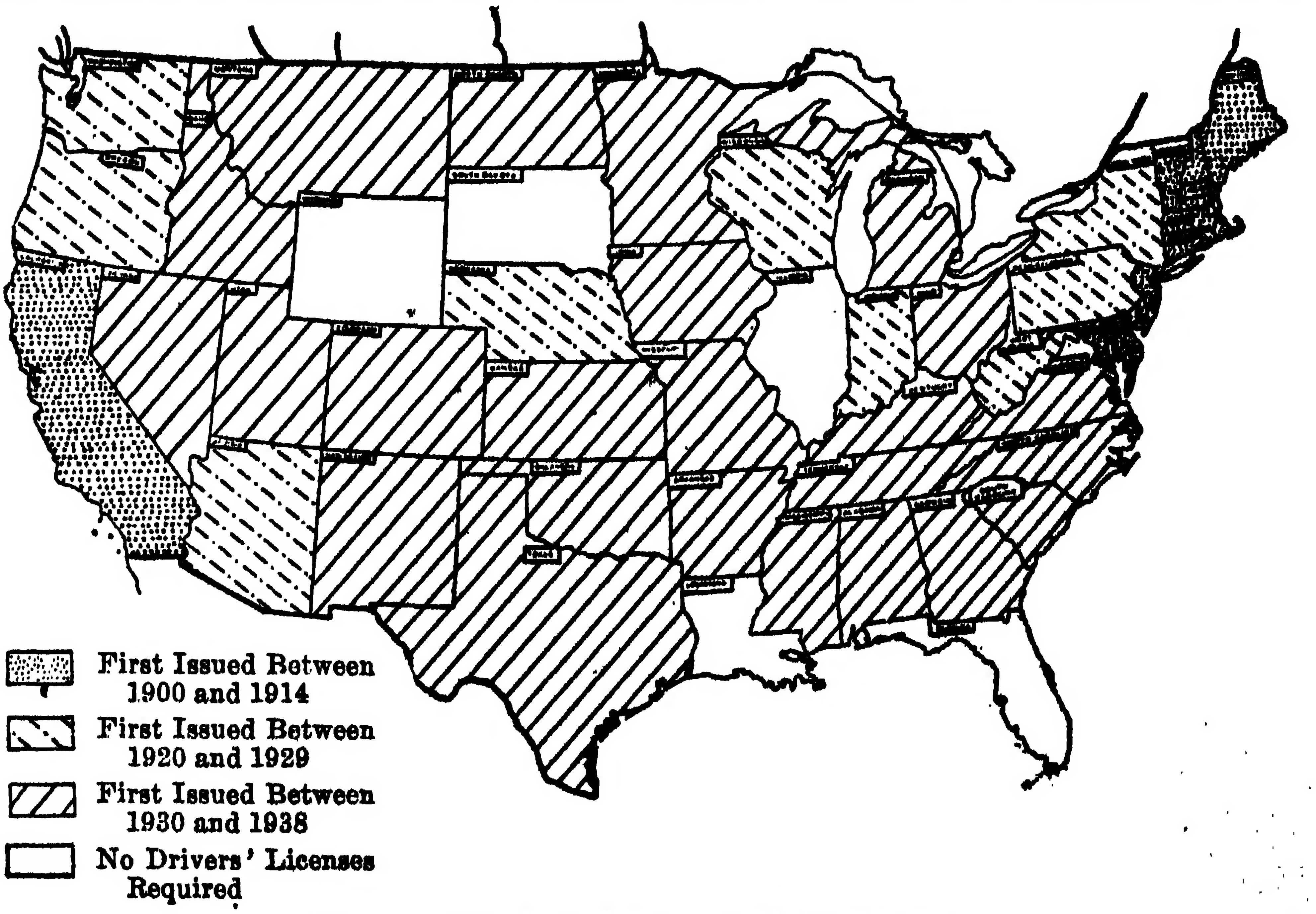


FIG. 1. DRIVERS' LICENSES—DATES OF ISSUANCE.

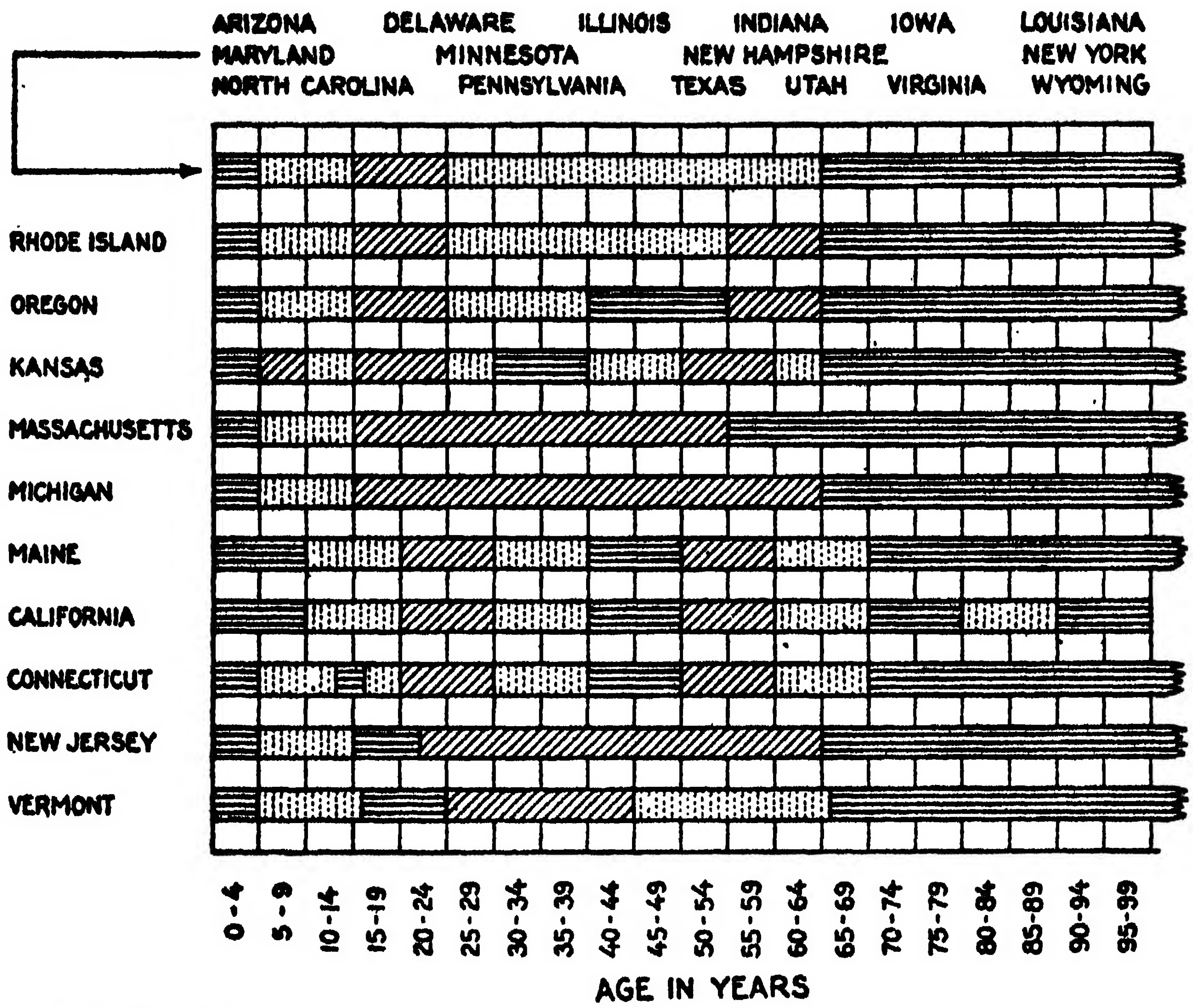


FIG. 2. GRAPHIC COMPARISON OF STATISTICAL AGE GROUPINGS OF ACCIDENT VICTIMS, USED BY 26 STATES (EACH DIVISION OF A BAR REPRESENTS A STATISTICAL GROUP).*

persons learn more slowly, and when they have attained a minimum standard of skill are more apt to be satisfied than youngsters. Many have never pushed on to the higher level of skill reached by present-day young people, so many of whom receive rigorous training followed by an examination. Add to this the fact that elderly persons learned to drive with old, noisy, slow cars with high seats and correspondingly easy visibility on uncongested highways, and one sees a reason for present-day maladjustments among our "old timers."

But in spite of its obvious importance there is a dearth of dependable facts about the relationship between age and motor vehicle fatalities. The reason is fairly easy to find. State motor vehicle departments whose records represent the only reliable source of facts about drivers have only in isolated cases become interested in age as a factor in accidents.

The statistical summaries of most motor vehicle departments contain age groupings that are too gross. The majority of states which do make statistical analyses of accidents divide the accident victims into three age groups, namely: (1) 15–24; (2) 25–64; (3) 65–over. There are, however, a few other groupings used (see Fig. 2). The point at issue is not which classification is the best. Any simple decade grouping would be satisfactory, but some uniform classification should be adopted throughout the country so that age statistics in different states could be compared.

The motor vehicle statistics now available do not indicate whether the individuals killed or injured are operators, passengers or pedestrians. Since the proportion of operators, passengers and

* From "Motor Vehicle Traffic Conditions in the United States," Part 3, U. S. Government Printing Office, Washington, D. C., 1938.

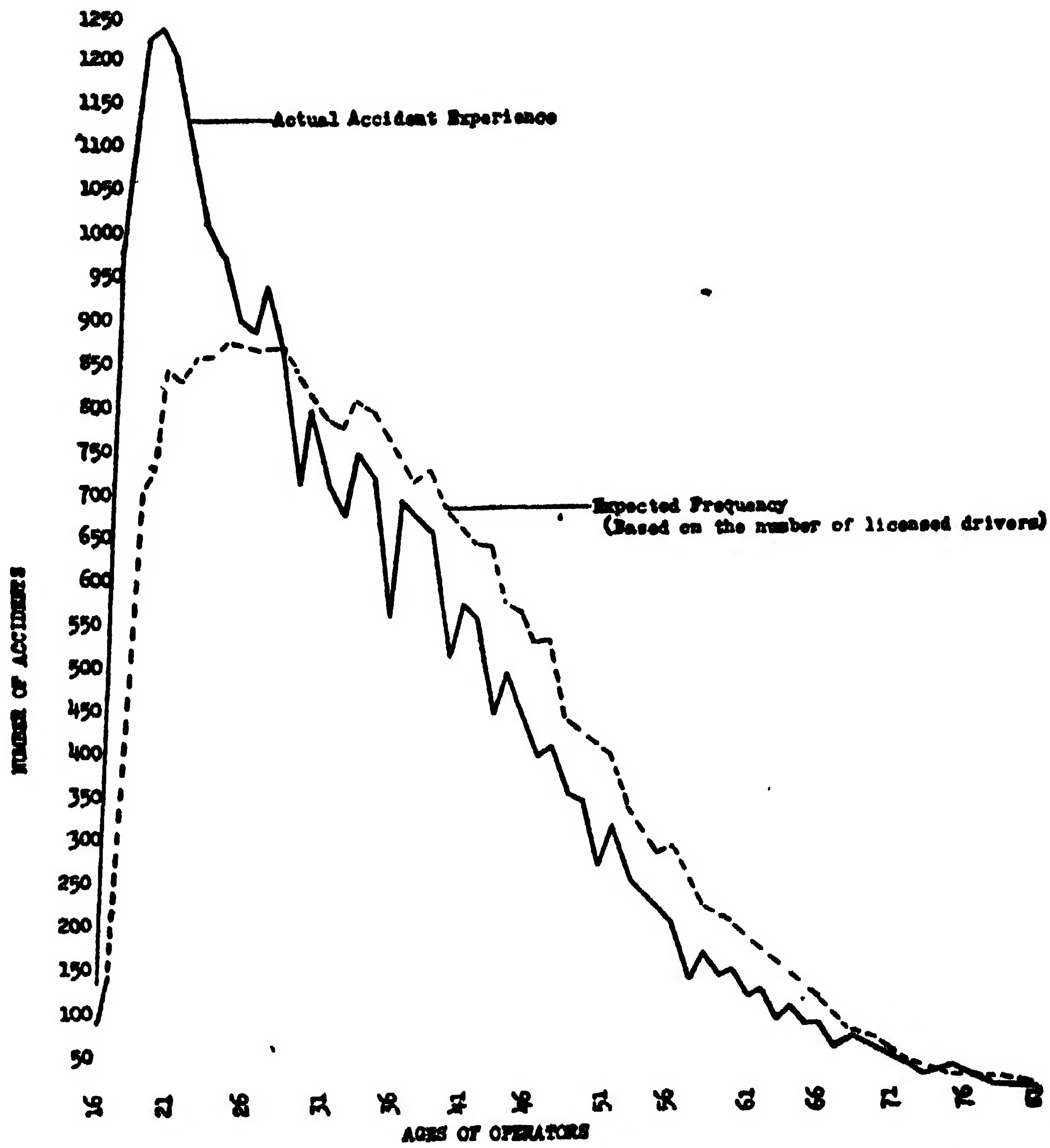


FIG. 3. COMPARISON OF ACTUAL TRAFFIC ACCIDENT EXPERIENCES, WITH EXPECTED ACCIDENT FREQUENCY.†

pedestrians on our highways varies from time to time, it is highly desirable to analyze the three groups separately.

It is particularly important to separate them in making any study of the influence of age, since we already know that accidents occur more frequently to drivers when young and to pedestrians who are old. Unless fatal accident figures are separated into operators and pedestrians it will be impossible to learn anything about the age problem.

Another weakness of present-day age statistics is that in only one state, Connecticut, has an age census of drivers been made over a period of years. In Connecticut an age census has been available since 1923. Up to 1931 it was divided into 10-year age periods. Since 1931 it has been broken down into 1-year age groups.

The Connecticut studies show that the average age of all drivers is 37, whereas the average age of all newly licensed drivers is 28. The average age of Connecticut drivers is increasing at the rate of one year with the passage of every four years. By 1950 the average age of Connecticut drivers should be about 40.

As can be seen by the accompanying graph (Fig. 3) the largest group of licensed drivers falls into the 20–29 year group. It is also noticeable that the drivers in the 20–29 age group have pro-

† From a study made in Connecticut Motor Vehicle Department by WPA project 3231.

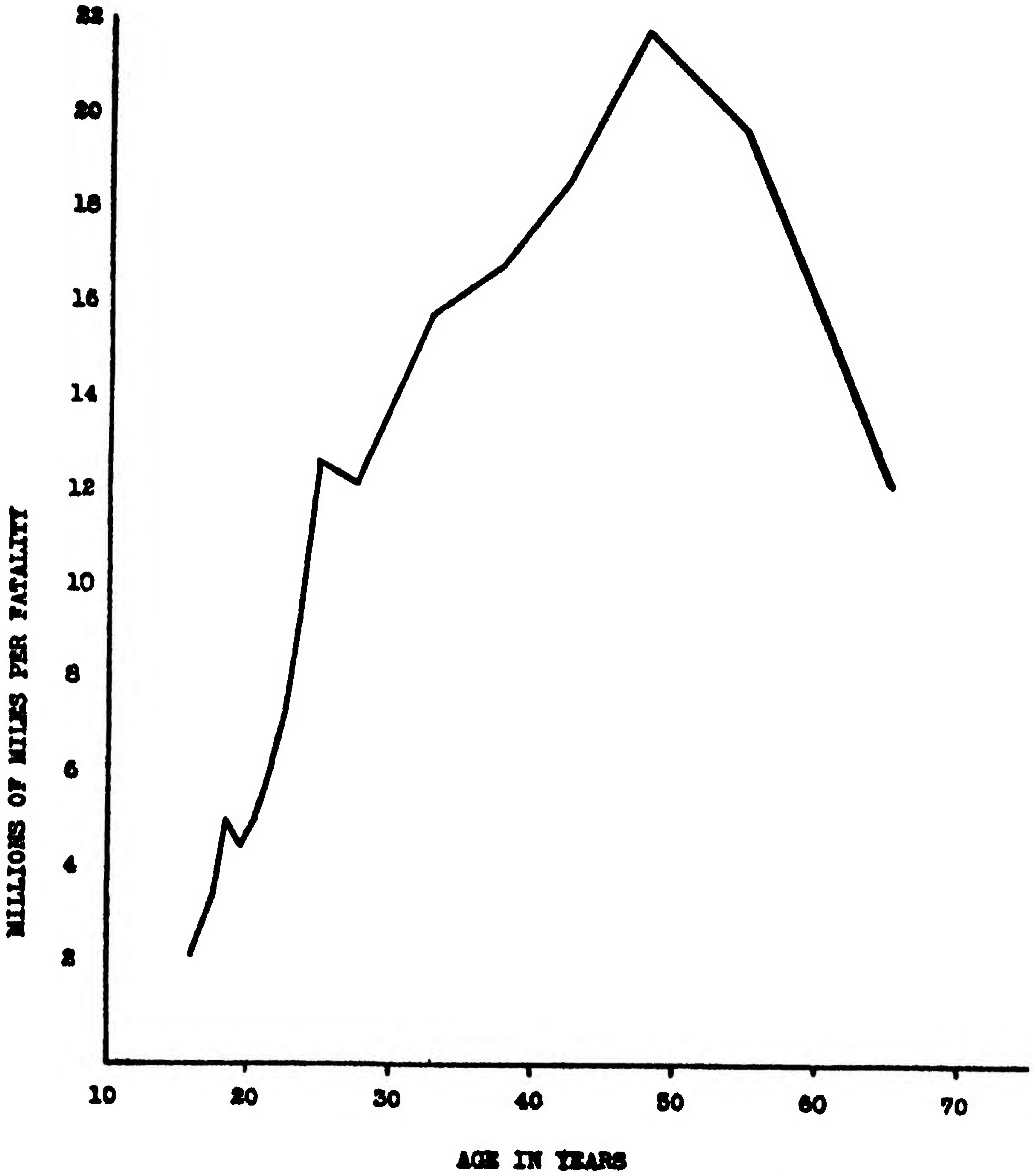


FIG. 4. MILEAGE DRIVEN PER FATALITY FOR DRIVERS OF DIFFERENT AGE GROUPS.‡

portionately more accidents than drivers in other age groups. Approximately the same number of drivers are in the 60-year group as there are in the 17-year-old group.

Taken by itself Fig. 3 would seem to indicate that our chief trouble is with the youthful offender and that the aged driver is a relatively unimportant factor. But before laying too much emphasis on the follies of youth we should take into account the exposure in terms of yearly mileage, the speed of driving, the age factor among pedestrians killed, the prevalence of intoxication and the different types of accidents.

‡ From safety and traffic engineering department, American Automobile Association.

Fig. 4 is taken from a study made by Burton W. Marsh, director of the Safety and Traffic Engineering Department, American Automobile Association. It reveals that young drivers between 16 and 20 years of age drove less than one fifth as far per fatal accident as do drivers between 45 and 50 years of age. Furthermore, with increasing age up to 48 there is an increase in the distance driven per fatal accident (in which drivers are involved). But beyond 48 there is a rapid decline in the accident rate in terms of exposure until by the age of 65 the driver is as unsafe as the 25-year-old one. According to these results both *the youthful driver in his 'teens and twenties and the elderly driver in the fifties and*

sixties are less safe than the adult in his thirties and forties. There are fewer drivers on the road beyond fifty, and although they drive less distance their accident rate starts to increase again.

Fig. 5 was compiled from the replies of over 1,000 drivers of different ages when questioned about their preferred open road speed. Since there was no compulsion to answering the question and since the person's name was not taken, it may be assumed that the answers were about their younger days. For in spite of driving at slower speeds the accident rate goes up beyond fifty.

Fig. 6 shows that the majority of fatal accidents involve operators and passengers who are in their twenties. Conversely, the majority of fatalities among adult pedestrians occurs in the fifties and sixties. The aging process takes its toll of the old pedestrian to a greater extent than the young one for a number of different reasons. Elderly people are not

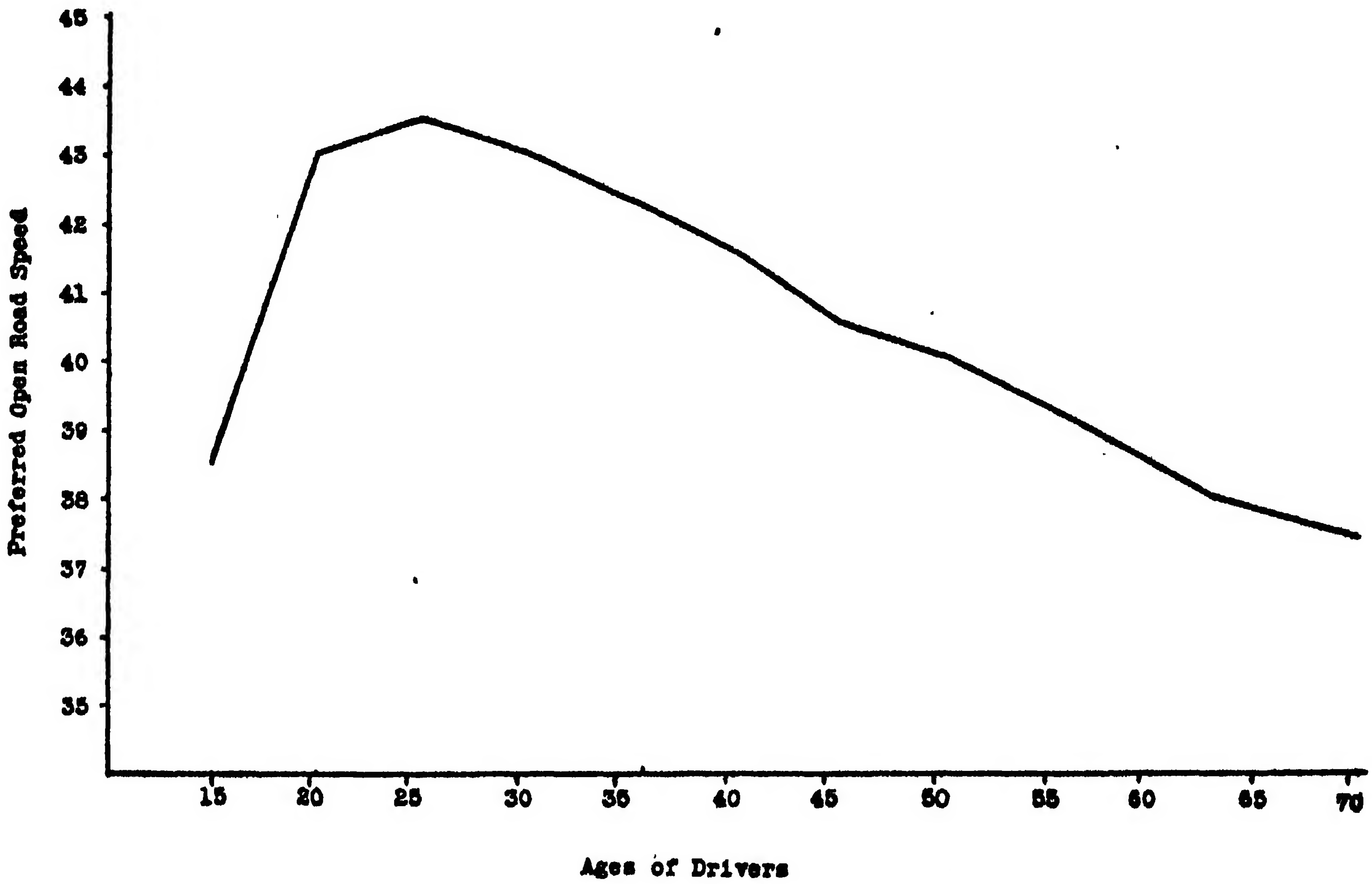


FIG. 5. PREFERRED OPEN ROAD SPEED AT DIFFERENT AGES.

as truthful as could be obtained. The curve shows that young people drive at higher average speeds. Possibly they are also more inclined to minimize their reported driving speed than their elders. At any rate, we have evidence that young people in their twenties not only drive farther than older persons but also faster. Were the fifty- and sixty-year-old drivers to drive as fast as the younger people they would undoubtedly have an even higher accident rate. Persons beyond their forties can not expect to continue to drive at the same rate as they did in as spry, they can not see and hear as well, and they succumb more readily to an injury. The older person as a pedestrian has even more need to be trained in safety than the aged motorist. A consideration of the death rate at the different ages as in Table 1 shows that the pedestrian in the fifties and sixties is the most dangerous risk. Since all motorists are also pedestrians, safety education among old motorists ought to help in the problem of training old persons to cross the highways safely.

Table 2 shows the incidence of alcohol-

TABLE 1

RELATIONSHIP BETWEEN HAZARD AND AGES OF PEDESTRIANS

Age	Number killed	Per cent. ped. of total killed	No. of years in age group	No. ped. killed for each year included	Av. no. of survivors of 100 born	Ratio of ped. killed to survivors
2 to 5 years incl. ..	13	93	4	3.2	83	39
6 to 9 " " ..	13	77	4	3.2	81	39
10 to 20 " " ..	7	25	11	0.6	79	8
21 to 30 " " ..	3	12	10	0.3	75	4
31 to 40 " " ..	22	56	10	2.2	69	32
41 to 50 " " ..	16	76	10	1.6	62	26
51 to 60 " " ..	30	88	10	3.0	53	57
61 to 70 " " ..	18	95	10	1.8	40	45
71 to 81 " " ..	10	100	11	0.9	23	39

TABLE 2

INCIDENCE OF ALCOHOLISM AMONG DRIVERS INVOLVED IN ACCIDENTS IN CONNECTICUT BY AGE OF DRIVER, 1930

Age	Alcoholic operators causing accidents*	All operators involved in accidents†	Per cent. alcoholic	Relative incidence all ages = 100
Under 20 ...	21	1,970	1.07	38
20 to 29	242	8,940	2.71	97
30 to 39	192	7,804	2.46	88
40 to 49	143	4,602	3.11	111
50 to 59	48	2,223	2.16	77
60 to 69	19	875	2.17	77
70 or more ..	3	225	1.33	47
Not stated ..	122	1,615		
All ages	790	28,254	2.80	100

* Number of alcoholic operators from Connecticut Department of Motor Vehicles Bulletin "If You Drink, Don't Drive, If You Drive, Don't Drink."

† Number of all drivers involved in accidents from "Statistical Summary of Traffic Accidents Caused in Connecticut—Calendar Year 1930."

ism among drivers involved in accidents in Connecticut. According to these results the driver in his forties is most frequently intoxicated in spite of the fact that we learned in Fig. 4 that this age driver is also the safest in terms of distance driven. There is, however, not much difference in the incidence of alcohol between the man in his forties and the man in his twenties and thirties. The reason more drunken drivers in their forties are detected is that more persons drink in their forties than at any other age. Since drivers beyond their forties become more prone to accident it behooves them especially to refrain from mixing drinking with driving.

The story of deterioration among elderly drivers can be told more graphically by charts than by words. Figs. 7 and 8 show (1) the gradual but steady decline of ability in steering coordination, (2) a slowing down in brake reaction, (3) an increased sensitivity to glare and (4) a larger number of rejections on road tests. Although this decline of ability is important and should be recognized and allowed for by persons as they grow older, the rate of decline has too often been exaggerated. The assets of the older persons, such as improved judgment, better emotional control and coolness in the face of emergencies, usually more than offset the slight loss of sensory capacity and motor control. As an example of the assets of the mature adult is his improved performance on our vigilance apparatus shown in Fig. 9. In this test the driver has first to respond to simple situations, and then to respond to a combination of situations at once. The degree of his improvement when performing under complex conditions as compared to his ability to perform in a simple situation is the measure of his adaptability and vigilance. In performance of this sort older experienced drivers invariably rank higher than young ones.

I shall now attempt to summarize weaknesses and strengths of youthful, middle-aged and old drivers and pedestrians. If this paper has devoted more of its attention to the elderly person it is because he is too often neglected as a source of accidents. Since the average age of both drivers and pedestrians is increasing we must perforce give more heed to them than heretofore.

Youthful operators unquestionably have the greatest accident incidence. The proportion of operators killed represents by far the largest of any age group. They drive more rapidly and travel

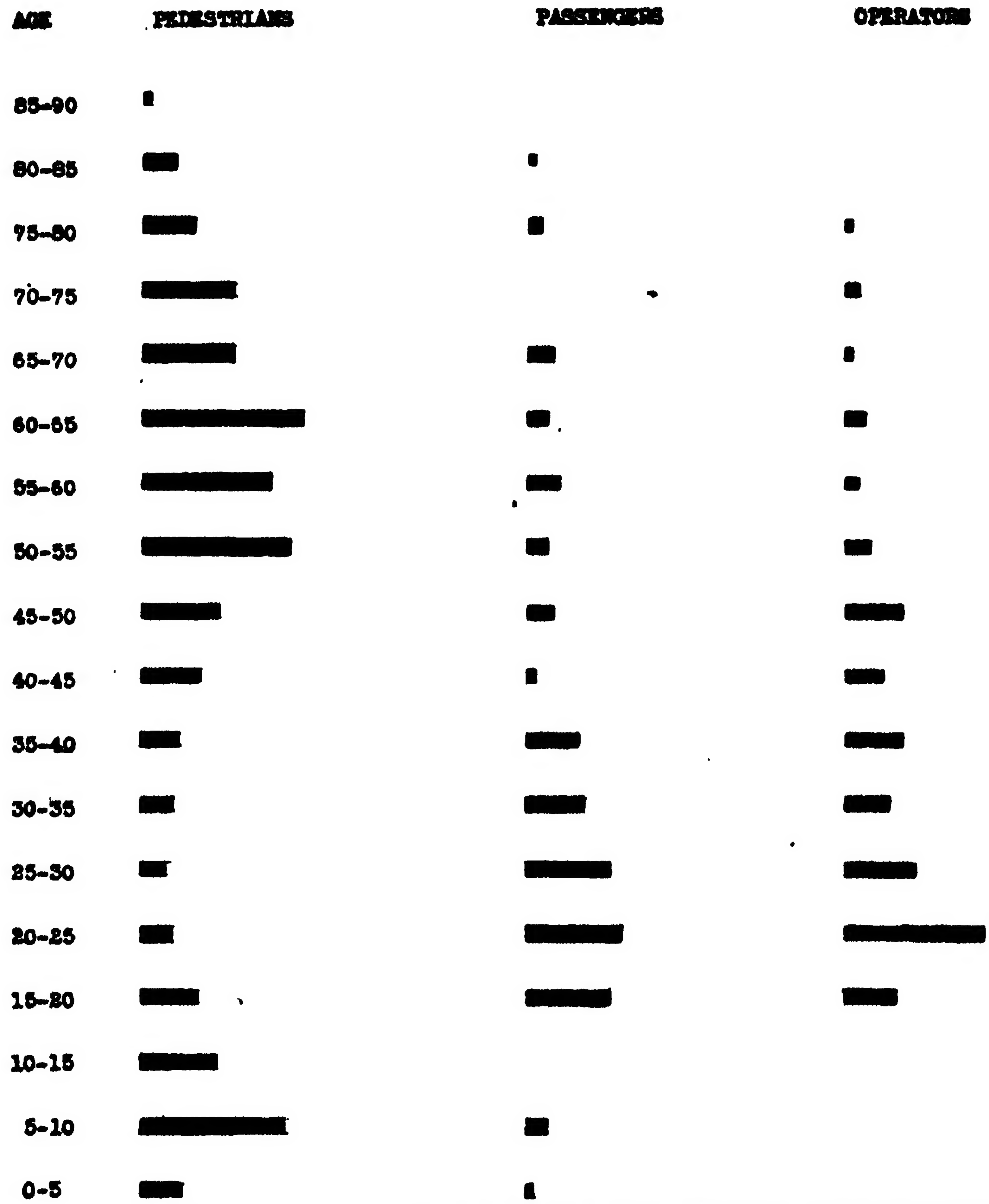


FIG. 6. AGE AND SEX OF PERSONS KILLED IN CONNECTICUT MOTOR VEHICLE ACCIDENTS DURING 1931.§

farther than older drivers. Having less experience and less responsibilities (there are fewer car owners and less married men in the younger age group) they undoubtedly drive with less restraint and are more interested in getting places in a hurry. They have less insight into their own faults and into the possible defects of their cars. Since they are continually exploring new and unfamiliar roads they are less well acquainted with the dangers that may confront them on the highway. Their ability to respond to complex situations and emergencies is not as good as it will be in later years. The chief redeeming virtue of young people is that they have keener eyes, more sensitive ears, quicker reactions and a better coordination.

§ From eighth study of motor vehicle accidents in the State of Connecticut by Richard S. Kirby, 1932.

All these abilities serve young persons in good stead and make them the safest pedestrians on the highway. This is fortunate indeed, since if they did not have these assets they would undoubtedly have a higher accident ratio as drivers, considering their high rate of travel and great yearly mileage and their habit of one-arm driving.

What is the solution as regards the

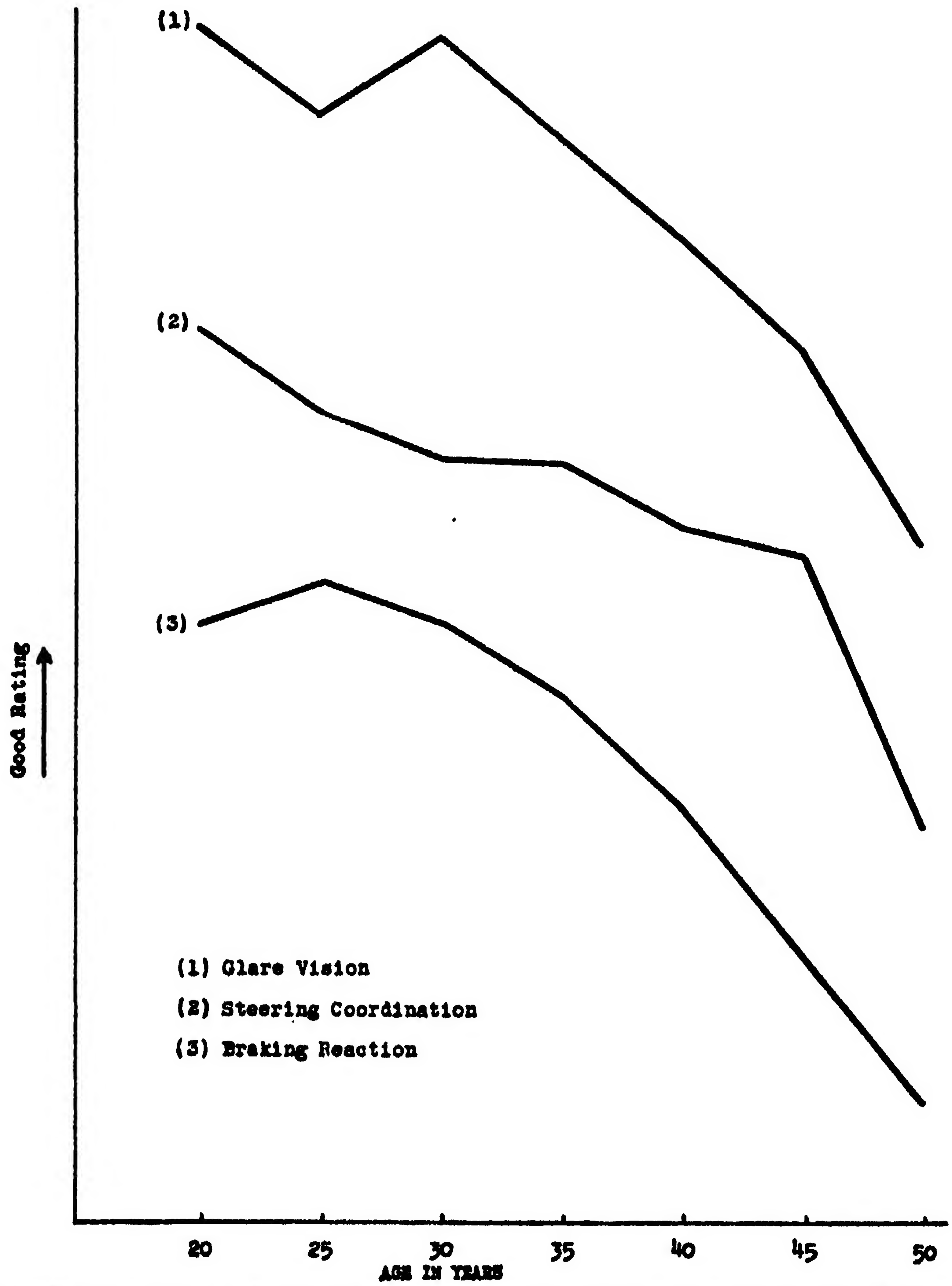


FIG. 7. GENERAL DECREASE OF ABILITY WITH AGE IN (1) SENSITIVITY TO GLARE, (2) STEERING OR EYE-HAND COORDINATION, AND (3) BRAKING REACTION TIME.

young driver? Training by a skilled instructor before being allowed to take a license examination; a comprehensive license examination designed to test the driver's facility in handling a car under various road conditions; a traffic law test; various sensory and coordination tests aimed more at giving him insight into his weaknesses than to disqualify him. As an example of the need of the latter type of test may I mention the following case: A trained driving instructor worked for weeks trying to prepare a youngster for his examination. He, by chance, brought the boy into a driver clinic and discovered that his depth perception was very poor. After being fitted with a proper pair of glasses, the boy took and passed his examination after only two more lessons.

Middle-aged drivers, having more experience and more responsibilities, have a better accident rate in spite of the fact that they drive almost as fast and as far as the younger group. An outstanding

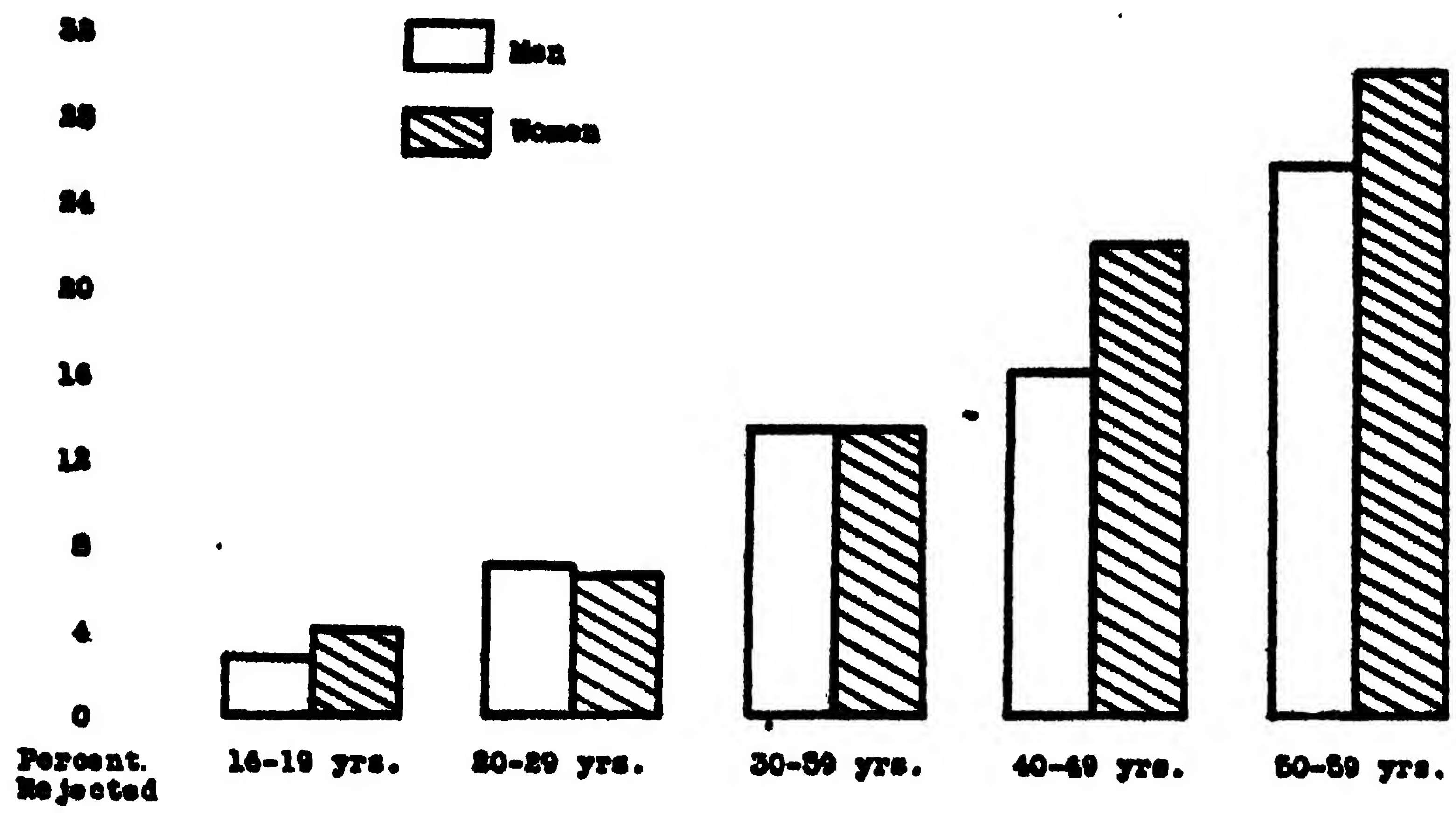


FIG. 8. PER CENT. OF APPLICANTS REJECTED ON ROAD TEST—ACCORDING TO VARIOUS AGE GROUPINGS.¶

paradox of middle-aged drivers is that during the period of least accidents (45–50 years) we find the greatest incidence of alcoholic drivers.

How can we improve the middle-aged drivers? By educating them to avoid mixing drink and driving. By re-examining in a driver clinic, such as is employed in the Wichita Police Department and the California Motor Vehicle Department, all drivers who have a serious moving violation or accident.[1]

The outstanding characteristic of the elderly driver is a decrease in sensory

¶ From a study made in 1932 by the Connecticut Motor Vehicle Department.

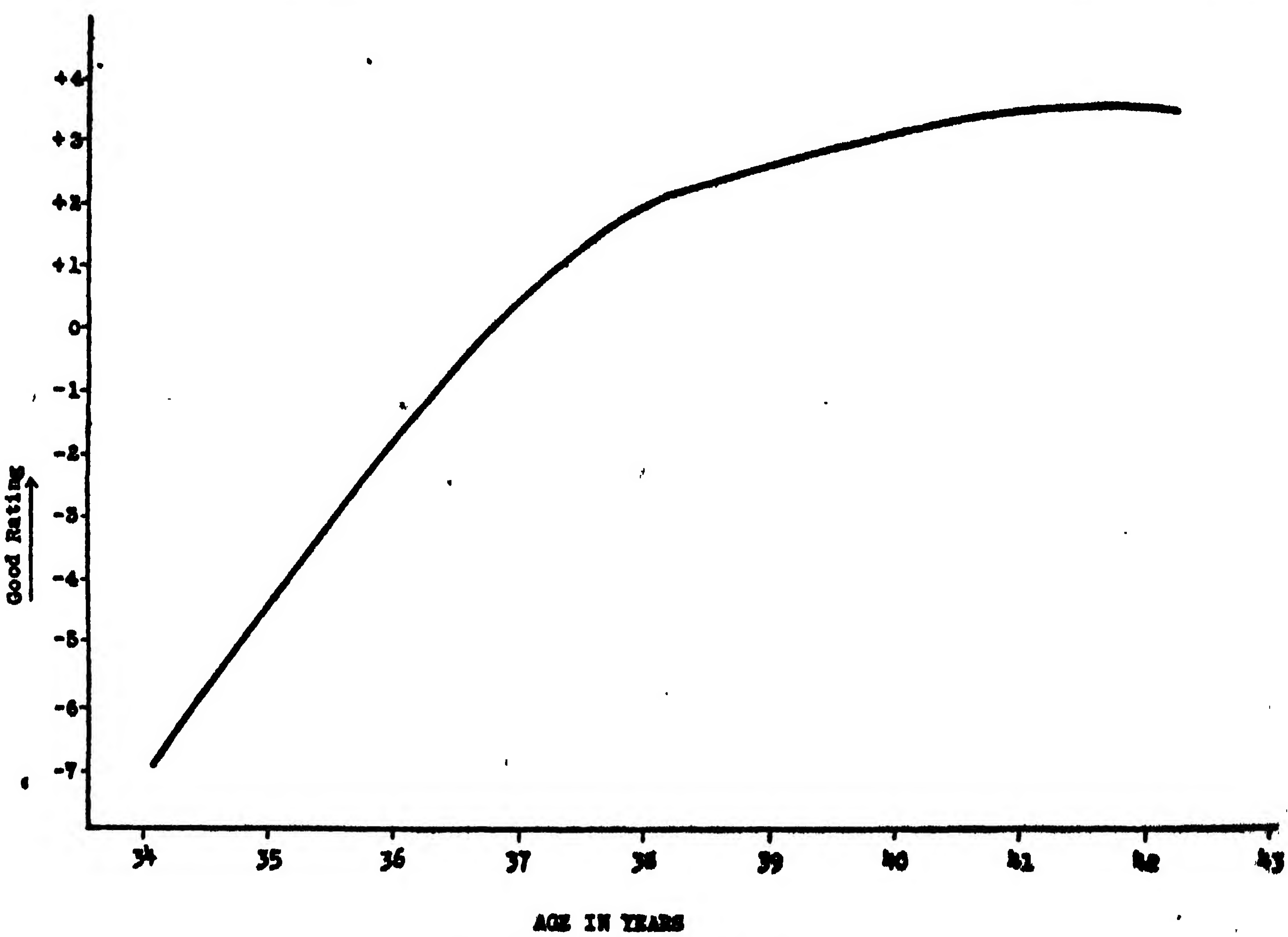


FIG. 9. COMPOSITE SCORE.

capacity and motor coordination. He is, accordingly, less able to handle himself, particularly as a pedestrian. On the other hand he has had much more experience in driving than the younger driver, and should be better aware of his own shortcomings as well as the defects in his car and the hazards in the road. Older persons, owning more cars and heading families, possess a keener sense of social responsibility, which is at the basis of driving courtesy and caution. On the other hand, many of them have never taken a license examination, nor learned to adapt themselves to the tempo of modern driving. Although they may not themselves get into so many accidents, on account of their slower speeds, more leisurely habits of turning corners and more cautious operations at intersections, they may, by hindering the steady flow of traffic, cause others to have accidents.

How can we help persons in their fifties and sixties to continue to drive as safely as they did in their forties? They can not be legislated into safety. Neither can they be browbeaten to drive more safely. Rather they must be approached individually and given objective facts about their failing abilities and how to adapt their driving to offset them. The driver clinic is more important for elderly persons than for younger persons. Detecting weaknesses not in one or two respects but in many respects the clinic supervisor can effect a better cure. Drivers like sick men can be cured best by helping themselves. When faced by objective facts old persons can carry out just as successful a self-improvement campaign as young persons.

[1] "Driver Testing Results," Monograph, *Harvard Traffic Bureau*, 1937, 98 pp. "Wichita Police Clinic," *Public Safety*, August, 1937, pp. 8–9: 45. "Clinical Treatment of Traffic Violators," *Police Journal*, December, 1937, Vol. XXIV, No. 2, pp. 3–7. "Driver Clinics in the Field," *Journal of Applied Psychology*, February, 1938.

SCIENCE BY RADIO

By Dr. F. R. MOULTON

PERMANENT SECRETARY, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

In these days of rapid political, economic and social changes, probably the most rapid and dangerous civilization has undergone, no one need apologize for attempting to place before the general public not only the facts but also the methods and the spirit of science, for science and its applications are the principal factors that are now transforming the world. Since the progress of science depends upon the social order, the relations of science and society are reciprocal. Consequently, the American Association for the Advancement of Science, which is dedicated to the promotion of science, is true to its declared purpose, even in the narrowest sense, when it serves the interests of society. But it is not necessary to insist on this reciprocal relationship between science and society, for the broad mission of the association is to advance the interests of civilization.

During most of its history the association was able to serve directly only its members and a limited number of other scientists. In recent years, however, noteworthy features of its meetings have been effectively and increasingly placed before the general public by the daily press. Now an amazing new means, the radio, is available for reaching the masses. Since January 19, 1938, the association has spoken weekly over the blue network of the National Broadcasting Company to all throughout the country who have cared to listen. Now fifty-seven broadcasting stations carry its programs under the general title "Science on the March," on Monday evenings at 7:45 Eastern Standard Time.

The "Science on the March" broadcasts are an experiment in mass education in the broad fields of pure and applied science. They have not presented science as magic or scientists as heroes. They have not attempted to startle the listeners or to represent science as consisting only of breath-taking discoveries. Such methods would violate the very spirit of science and encourage beliefs in magic not only in science but also in all the affairs of life. They would prepare the way for mass hysteria such as that which swept over the country in terror of an invasion by utterly fantastic creatures from Mars. The broadcasts of the association represent science rather as enthusiastic and joyful, yet sane and systematic, explorations of the universe about us and in us. Disavowing beliefs in mysteries and magic, they advocate confidence in experimentation and the processes of reasoning.

Ideals are one thing, and their accomplishment is often quite another. And so it is with education by the radio, for the radio has so recently become available that its possibilities are practically unknown. It is so different from other methods that previous experience is of little value in attempting to use it. An obvious advantage that it has is that an exceptional teacher may reach simultaneously an enormous number of persons of all ages, occupations, education, cultural background and intelligence. An obvious disadvantage of the radio in education is that it provides only one connection between the teacher and those who are taught, and that connection is one-way, brief, leaving no permanent record and without opportunities for repetitions. Clearly a means of education that is so new, that offers certain very great advantages and that is beset by serious difficulties deserves careful consideration and a large amount of experimentation. As has been remarked,

the broadcasts of the association are in the nature of an experiment in mass education in a difficult field.

Before the "Science on the March" broadcasts were initiated the method of their presentation was given considerable attention, and the final plans for them were agreed upon in a conference with Dr. James R. Angell and Dr. Franklin Dunham, of the National Broadcasting Company. Every one agrees that the first principle in education is to cause the learners to think. Socrates became perhaps the most famous teacher in history, not because of brilliant lectures or carefully prepared outlines of courses, but because he taught those who sat at his feet how relentlessly to doubt and to question and to work out their own answers. And it is true that all the great teachers whom we have known or whose reputations have come down to us have stood out above other members of their profession because they followed essentially the same method. This attitude has always been the chief characteristic of great teachers whether their special interests were in the dead languages or philosophy or science or theology—whether they looked back over the past or sought to penetrate the future. In this method two minds strive together and sometimes clash on terms of approximate equality.

Since over the radio it is impossible for the teacher and the person taught to sit together on a log and discuss the questions in which they are interested, the participation of the listener must be vicarious, as it is in the printed story. In a good story the reader identifies himself with one of the characters. The adventures, the hopes, the anxieties, the failures and the triumphs of the hero are his. The satisfactory hero sometimes is foolish and makes mistakes, he sometimes is discouraged, but he persistently rises above difficulties and in the end he triumphs. He must have some human frailties or the reader can not identify himself with him; he must have some heroic qualities for the reader to look up to as a standard.

In formulating plans for the broadcasts of the association, the advantage of the method of Socrates was kept always in mind. The attempt has been made to make the listeners participants in the discussions rather than simply recipients of what has been said. Since they can participate in the broadcasts only as readers of a book take part in its story, a leaf has been taken from "Pilgrim's Progress" and "The Last of the Mohicans" and "Little Women" and other books that have profoundly influenced the lives of the youth of our land. The speaker and the announcer are the characters, the latter representing the listener. In Socratic fashion they question and argue, sometimes following false trails, sometimes reaching premature conclusions on insufficient evidence, often triumphing, but sometimes being compelled frankly to admit that they do not know the answers to the questions they are considering. That is the way it is with scientists and with all honest, inquiring minds.

Such are the ideals, but the broadcasts often fall far short of realizing them. It is a somewhat onerous burden to prepare and deliver at a fixed time a broadcast week after week in the midst of many other duties. Often the inspiration for the right touch is lacking. Sometimes the choice of subject is not fortunate. Sometimes a broadcast is too elementary for some listeners and too stilted for others. There are very many ways in which to fall short of success. Yet letters from many listeners prove that the broadcasts have achieved a considerable measure of success. Between January 19 and October 1, 170,600 copies of scripts of the broadcasts were sent out free of charge to those who asked for them with the help of a grant from the Carnegie Corporation of New York in aid of the educational work of the association.

In order to obtain specific information respecting the public that was interested

in the broadcasts and the use that was being made of them, in June a somewhat detailed questionnaire was sent out to about 8,000 persons. Nearly 2,000 of these persons took the time to reply to the questions and went to the expense of returning the questionnaire. Of these replies, 1,250 were chosen at random and the answers and the voluntary remarks they contained were tabulated. The following is a summary of the results:

	Per cent.
1. *Occupations of listeners*	
Business and clerical work	16.6
Professions exclusive of teaching	11.8
Farming and housekeeping	7.2
Teachers	10.3
Students	35.2
Skilled labor	8.0
Unskilled labor	3.1
None (retired, unemployed, invalids)	5.6
Occupation not given	2.2
	100.0
2. *Education of listeners*	
College degree	28.1
High-school graduate	21.4
Grade-school graduate	6.9
In school at present	35.2
Education not given	8.4
	100.0
3. *Conditions of listening*	
With family or friends	60.7
Mostly alone	33.9
With science clubs, classes, scouts	3.1
Not able to listen but use scripts	1.8
	100.0
4. *Use of printed scripts*	
File for personal or family use	71.7
File for friends, employees, customers	8.9
Use in science clubs, schools, scouts	27.8
Use for lectures, sermons, rebroadcasts	.3
Dramatize or read aloud at home	12.8
Dramatize or read in clubs or scout meetings	2.7
Dramatize or read at school	6.1
Dramatize or read at other places	5.8
Total, including duplicate uses	136.2
5. *Discussions of broadcasts*	
In homes	51.1
In schools, clubs, churches	31.1
At work and with friends	6.8
No information given	11.0
	100.0
6. *Suggestions and requests*	
Organization of radio science clubs	44.9
Inclusion of lists of books and magazines	19.1
Broadcasts in school hours for students	1.9
More frequent or longer programs	5.0
Questions to be answered	1.1
	71.9
7. *Subjects requested for broadcasts*	
Astronomy	21.1
Geology, etc.	14.4
Medicine	11.1
Chemistry	10.3
Physics	9.9
Biological sciences	8.7
Recent scientific discoveries	8.5
Scientific theories	7.0
Biography of scientists	4.7
Radio and television	4.3
	100.0

Among the many interesting facts contained in this summary, the most significant is that more than 60 per cent. of the persons reporting listened to the broadcasts with family and friends. These were more than casual family gatherings, for in more than 51 per cent. of the cases the broadcasts were discussed in the homes of the listeners. Indeed, in about 13 per cent. the printed scripts were later read aloud. It is doubtful whether there is any more satisfactory form of general education than free and informal discussions around the family fireside without any compulsion or even the formalities that are necessary in schools. Many of the applications of science tend to weaken family ties; perhaps the radio can be made a very important force in restoring them and raising them to a higher level. If so, it may become for this reason of great service to our civilization.

Of similar import is the fact that nearly 28 per cent. of those reporting use the printed scripts in science clubs, schools and scout meetings, and that more than 31 per cent. discuss the broadcasts in clubs, schools and churches. Consequently, these experiments make it clear that broadcasts may help not only to unify the family but also to integrate community life.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]
WASHINGTON, D. C.

"MONSTERS" TO MARS

If "monsters" from Mars should ever descend upon the earth and spread destruction, as a recent broadcast represented them as doing, an obvious counter measure would be for all terrestrial nations to combine and retaliate by sending "earth-monsters" to Mars. As a precautionary step the basic scientific facts on which the project would depend should be worked out well in advance of their need. Some of the dynamical principles involved and the difficulties which would be met will be enumerated. Even if the idea of an invasion from Mars or of a retaliatory expedition from the earth is fantastic, it raises interesting scientific questions that have astonishing answers.

Inasmuch as the "earth-monsters" would have to pass through at least forty million miles of vacuum, it would be necessary for them to be enclosed in an air-tight vessel of some sort, presumably a sphere. To serve its purpose the sphere would have to be large enough to hold a considerable number of the "monsters." A conservative estimate would assign it a diameter of twenty feet, and the materials of its walls would have to be strong enough to withstand the strains to which it would be subjected.

The first question to be considered is the thickness of the walls of the sphere that would be necessary. Under the assumption that normal atmospheric pressure would be maintained in the interior of the sphere, we find that when it got out into a vacuum the total outward pressure would exceed 2,700,000 pounds. Naturally this pressure would tend to rupture the sphere, but we find that if it were made of good steel a thickness of one tenth of an inch would give a good margin of safety. With this thickness the empty sphere would weigh about 4,800 pounds.

A serious difficulty arises, however, in getting the sphere out into space free from the gravitational control of the earth. It is well known that if it were simply shot outward, it would have to leave the surface of the earth at a velocity of seven miles per second in order to escape. In fact, it would have to be projected outward at a much higher velocity, for seven miles a second is the velocity that would be necessary if there were no retarding atmosphere. Now seven miles per second is approximately ten times the muzzle velocity of a very high-power gun, and no method is known of producing such a speed, or even one quarter of such a speed, in a projectile.

Let us ignore the serious difficulty of starting the sphere out from the surface of the earth at a velocity of seven miles per second and consider the resistance of the atmosphere to which it would be subjected. At this high velocity the atmospheric resistance would be about 23,000 pounds per square inch, or a total of more than 500,000 tons on the forward side of the assumed twenty-foot sphere. Therefore a sphere one tenth of an inch in thickness would fall short of being strong enough. Moreover, the resistance of the atmosphere would be 200,000 times gravity, and consequently for the sphere to escape from the earth its initial velocity would have to be much greater than seven miles per second, perhaps ten times as great, or a hundred times the muzzle velocity of a high-power gun. But since the atmospheric resistance increases with the square of the velocity, it would rise

[1] With the exception of the two signed statements these notes have been prepared by Science Service; Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

to a height which no known material can withstand. Consequently "earth-monsters" can never be shot outside the earth's atmosphere.

There is, however, another possibility to be considered, that of a huge rocket which propels itself by shooting backward part of its material. That there is something in the idea is proved by the success of sky rockets on every Fourth of July. The principle involved is illustrated by the kick of a gun when it is fired: the projectile goes forward at high speed and the gun backward at low speed, the velocities being inversely as the masses. Or, otherwise stated, the product of the mass and the speed of the projectile in one direction equals the product of the mass and the speed of the gun in the other direction, except for slight effects of expelled gases and attachments to the gun. In the case of heavy artillery, such as is used on naval vessels, elaborate means must be provided for taking care of the recoils of the guns. An obvious advantage of a rocket is that since the propelling force is applied gradually, high velocities, and consequently large resistances by the atmosphere, are not developed. On the other hand, all the materials that are projected backward during the flight of the rocket must be carried along at a great cost of energy until they are used. In order to get some idea of the practical aspects of the problem, it will be assumed that the twenty-foot rocket is launched with an initial velocity of only one quarter of a mile per second, which is well within the muzzle speed of guns, and that enough material is fired backward to maintain that velocity until the rocket has reached an altitude of one hundred miles, beyond which there will be no appreciable amount of atmosphere. At a speed of one quarter of a mile per second the atmospheric resistance to the rocket at the earth's surface would be 1,300,000 pounds and, gradually diminishing with altitude, would vanish at a height of one hundred miles. The gravity of the earth would be sensibly constant to even a much greater distance from the surface.

In order to get the rocket beyond the earth's control there are two forces to be overcome, the resistance of the atmosphere and the backward pull of gravity. The work that would have to be done in moving the rocket against the resistance of the atmosphere from the surface of the earth to a height of one hundred miles would be, under the assumption of a constant speed of one quarter of a mile a second, thirty billion footpounds. If the rocket with its load weighed ten tons, which is less than the weight of a twenty-foot hollow sphere with even a half-inch steel shell, the work required to get it beyond the control of the earth's attraction would be 420 billion footpounds. Consequently, in order to get the rocket out through the atmosphere at a velocity of one quarter of a mile a second and beyond the control of the earth's gravity, the material shooting back from it would have to do on it 450 billion footpounds of work. But to do this enormous amount of work would require, even at 100 per cent. efficiency, as much energy as there is in sixteen thousand tons of coal. Since a rocket weighing only ten tons could not carry an initial load of sixteen thousand tons, the impossibility of "earth-monsters" going on a successful expedition to Mars is quite evident. And the difficulties in the way of "Mars-monsters" getting free of that planet are comparable, not to mention as serious ones in traveling many millions of miles through interplanetary spaces. So let the silly season for "Mars-monsters" come to a close.

F. R. M.

HUMAN CONSERVATION

Conservation of America's mental health should obviously be one of the first concerns of the nation. Yet it is receiving much less attention at present than is the conservation of soil.

The functioning of a democracy presupposes that the citizens must be intelligent, informed and in their right minds. Yet, an estimated 1,500,000 persons in the United States are mentally defective. Another 1,500,000 to 2,000,000,000 are mentally diseased.

Mental disease is America's worst health problem. Six of every ten hospital beds are occupied by mental patients. Unknown numbers are being cared for outside institutions. Yet the facts behind mental disease are as unknown scientifically as are the facts about cancer.

An extensive series of surveys of mental health in typical American communities is strongly urged by the Committee on Population Problems of the National Resources Committee, whose report has made public these facts.

Such surveys might assay the nation's intellectual resources, reveal the need and suggest methods for conservation, and possibly throw light on disease causes.

Economic factors, including unemployment, may be found to contribute to mental breakdown, and the differential birth rate which brings the largest families to the worst homes may be found to contribute alike to mental defectiveness, mental disease and social inadequacy.

"In the past we have as a nation considered our natural and our human resources alike to be virtually inexhaustible," warns the committee. "It has come as rather a shock in recent years to learn that the acreage of formerly fine farm land that has been permanently destroyed runs into a staggering number of millions.

"In exactly the same way our human heritage is not inexhaustible. Millions of years have gone into building it up, just as in the case of the soil. The possibility of the wastage of genes favorable to human development through social conditions causing adverse selection suggests a more serious national problem than any amount of soil erosion."

The development of a "human conservation" policy is urged.

WHY LEARN TO READ?

Why learn to read?

Modern invention is fast minimizing the need for ability to recognize the printed word. The radio has done away with need for reading the newspapers; even the comic strip is presented over the air. Fiction comes to you in sound movies.

You can now buy excellent magazines containing whole stores in pictures. Even if you are a historian, important events are recorded for you in motion pictures. The voices of great men may bring their messages to you on sound film or phonograph records.

Even the letters of friendship or business may soon be outdated by mailable dictating machine records on which the sender can speak directly to his correspondent.

Seriously, it is proposed by Dr. Arthur Lichtenstein, of the Johns Hopkins University, who has had the problem of teaching reading to those who can not learn, that we modify the school curriculum so as to lighten the burden for those lacking in literary aptitude.

The story of Rae is told by Dr. Lichtenstein in *School and Society,* where this revolutionary proposal is made.

Rae was a "nice, friendly boy, making every effort to succeed, and a great help around the home."

Rae's troubles were due to the fact that at ten years he was unable to pass the second grade reading test. Despite this handicap his intelligence was normal. Every effort was made to teach him to read.

Four years later his IQ had dropped 15 points. He had gained 18 months in mental age in the four years and in silent reading he had lost two months.

"The time spent in attempting to make a reader of Rae was wasted," comments Dr. Lichtenstein. "Fortunately,

no greater harm to his personality appeared to result than the development of a marked inferiority feeling and dislike and apprehension in the presence of a reading situation.

"Had reading been relegated to a minor place in his program instead of the all-powerful bugbear it became, he would be just as well off educationally and far better off from a mental hygiene point of view."

WATERSIDE IMPROVEMENTS

WITH a new public works program about to get under way, it is worth while taking a critical look at plans for some of the improvements that are intended at once to make our communities more livable and to give jobs to the unemployed. Too often, public improvements have been synonymous with wholesale destruction by grader and steamshovel.

Recently a group of European conservationists and landscape engineers got their heads together and drafted a set of rules to be consulted when waterside improvements are being made. Their suggestions are worth pinning on the walls of local public works committees—and pasting in field supervisors' hats:

(1) Improvements should leave the landscape as nearly as possible in its original state, or at least able to return to that state very quickly.

(2) River courses should be changed only when absolutely necessary; and then they should not be made rigidly straight, but laid out in gradual curves.

(3) Islands, as ideal breeding places for wildlife, should not be destroyed or disturbed.

(4) Streamside vegetation should be left undisturbed as far as possible. If a stream must be widened, the cut should be made on the side with the least timber.

(5) When trees and shrubs must be removed, they should be replaced immediately, preferably with native species.

(6) New banks on a cut should be of natural materials, such as sod, brush and broken stone; concrete walls are to be avoided.

(7) Natural lakes and ponds should not be drained or destroyed, and their shore vegetation should either be left undisturbed or restored to its natural state as quickly as possible.

(8) Planners should carefully consider whether projected improvements will cause a lowering in the water table.

(9) Bridges, dams, etc., should utilize local material as far as possible.

(10) Long, straight lines in dikes, levees, etc., are to be avoided.

(11) Drainage projects should spare trees and shrubbery.

(12) Definite plans should be fully worked out before digging begins.

ON THE SANDS OF TIME

KENNETH JONES, village carpenter at Mortlach, Saskatchewan, hunts Indian arrow heads in his spare time. For some years now he has been picking up curious chipped flint spear heads, accounts of which sent Dr. Frank H. H. Roberts, Jr., Smithsonian Institution archeologist, on a flying visit last month to the little Canadian town. The pieces of stone were Folsom and Yuma points, artifacts of men who lived in North America at least as early as the later stages of the last ice age—probably as much as ten thousand years ago.

Dr. Roberts found himself in a dismal country wrecked by draught and wind, the Canadian dust bowl. But at some time in the distant past it had been a pleasant land with little lakes strung like amethysts down a long valley. It was then very likely, Dr. Roberts believes, that the ancient nomad hunters, who were the first human beings to leave any traces of themselves on this continent, camped there.

The Saskatchewan carpenter's spearhead collection may prove a key to a hitherto impenetrable chapter of history. The ancient hunters themselves or their direct ancestors undoubtedly came into

the interior of North America from Asia by way of Alaska. For five summers Dr. Roberts has been excavating the site of one of their camps in northeastern Colorado, which, it has been demonstrated by geological evidence, was just at the edge of the retreating glacier, from which summer streams created lush meadows in which grazed great herds of an extinct species of bison and camels, musk oxen and a few mammoths.

How did men get there? To the north was a limitless waste of ice like the interior of Greenland to-day. Human beings hardly could have made their way across it for thousands of miles, even in many generations. The only possibility is that there was a broad, ice-free corridor, for which there is considerable geological and botanical evidence, at some time during the Pleistocene, which would have included the Canadian dust bowl.

This may have been the time when the nomad hunters, on their slow way south, camped around the Mortlach lakes, and in this case the curio-collecting carpenter may have hit upon the earliest trace of human beings in North America. Otherwise, Folsom man must have waited for the retreat of the ice to get there, for there is geological evidence that the corridor was closed during the last part of the Pleistocene.

Unfortunately the evidence is vague. The winds have wrecked any semblance of soil stratification in the area so that the finds can not be dated. But, somewhere in Alberta or Saskatchewan there may be an undisturbed site where Folsom man camped, and whose fortunate finder will have hit upon one of the key spots of North American archeology.

THOMAS HENRY

ALGAE AS SOURCE OF FOOD

MOST of us, even though we may claim no great degree of botanical knowledge, can recognize the lesser plants, fungi and mosses, when we see them. But mention algae, another great group of the humbler, flowerless growths, and we feel a bit lost. We aren't quite sure what algae are.

To bring popular knowledge of this important but neglected province of the plant kingdom up even with that of plants in general is the task which Professor L. H. Tiffany, of the University of Illinois, has set for himself in his new book, "Algae: the Grass of Many Waters" (Thomas).

Algae are not grasses, in the strict botanical sense of the term, the author points out. They rank far below grasses in the hierarchy of systematic botany, indeed sharing with fungi the lowest rung of the evolutionary ladder. Yet styling them "grass" is justified from the ecological point of view, because of their function in the life-complex of the waters. If it is true on land that all flesh is grass, it is equally true in the water that all fish is alga.

Algae form the fundamental food in the long chain of eat-and-be-eaten that begins with some almost invisible gnawers like minute worms and water-fleas and builds up at last into salmon and sturgeon, walrus and mighty whale. Most of us know algae mainly as the highly unappetizing green scums that form on stagnant ponds; we do not recognize in it the fish-fodder that eventually turns up on our tables after many digestive metamorphoses.

But algae are not just fish provender. They come to our notice, and affect our lives in a score of other ways. They form green mats and scums on the soil and apparently cooperate with bacteria in fixing atmospheric nitrogen as free fertilizer. They form the green "moss" supposed to grow only on the north sides of trees. (Actually it grows on any damp side of the trunk.) Fossil beds of their silica shells provide scouring powder. Algae have even been found inhabiting our own important interiors.

THE RUINS OF HITTITE PALACES

THE mysterious Hittites are not nearly so mysterious as they used to be. Archeologists are persistently digging up Hittite cities in Asia Minor and Syria to the north and northwest of Palestine. As a result, Hittites are now classed respectfully with the big powers of antiquity, and their two eras of expansive empire, when they dominated wide regions of the ancient world, are being restored in some detail to pages of history.

One gap in knowledge of Hittite fortunes has been the time between 1650 B.C. and 1400. That was between the two great empire eras, when Hittite kings seem to have lacked the militaristic urge to power.

So, it is a red letter Hittite day when Sir Leonard Woolley, excavating for the British Museum at Atchana near Antioch in northern Syria, finds a Hittite palace built about 1600 B.C. and burned near 1400.

Whether the era was considered a time of fortunate peace or one of weak depression by people in those days, the palace ruins at Atchana suggest that Hittite rulers there lived well and conducted business as usual.

Wrecked by fire though it was, the palace ruins tell a lot to an archeologist. Sir Leonard identifies suites of rooms with bedroom and bath and points out women's apartments marked by the combs, pins, trinkets and toilet boxes in the debris. Other rooms containing little besides clay tablets and wine jars are presumed to belong to scribes—the secretaries and clerks of the palace.

In one annex to the palace is a suite of work-room, bedroom and lavatory, which belonged apparently to the archivist, since a room built especially for storing records is near it. Most of the tablets stored here were removed in the fire 3,400 years ago, but elsewhere in the annex offices about 300 clay documents awaited the archeologists of 1938. These may add history of the obscure era.

THE APPRECIATION OF MUSIC

LOVE for music can be explained by the psychologist. Dr. Carl E. Seashore, of the University of Iowa, who as psychologist has for years been studying and predicting musical ability and appreciation, scouts the idea that love for music is an inexplicable emotion.

Love of music can be accounted for on five grounds, he writes, in the *Music Educators Journal*. The first reason is physiological. We have an organism that registers music and responds to it somewhat like a resonator. Not only the central nervous system is affected, but the peripheral nervous system, all the muscles, all the internal organs, and especially the autonomic system with its endocrines which furnishes a physical basis for emotion. The whole body is put into a glow of well-being by the pleasure of hearing musical sounds.

A single sound may be beautiful in itself, like a flower or a human face. The untutored mind and the musically trained can alike delight in their charm quite apart from their utility in building up musical form.

Delight in "harmonic structure, the melodic progressions, the rhythmic patterns, the qualitative modulations, in the flow of beautiful sounds" is another reason for love of music. Music carries us through the realms of creative imagination.

We love music also because it is the language of social bonds. Music is a message and can move the social group into concerted action and into a feeling of common fellowship.

Finally we love music because it is a means of self-expression. It furnishes us with the joy of putting into a fitting medium our love, our fears, our sympathy, our feelings of fellowship, our communion with the Divine.

On these five fundamental grounds, says Dr. Seashore, rests the psychologist's adequate explanation for why we love music.

NEW CURES FOR OLD

By Dr. JAMES FREDERICK ROGERS
OFFICE OF EDUCATION, WASHINGTON, D. C.

In man's earliest endeavor at finding the source of his aches and pains, his fevers and his prostrations, it was a somebody, not a something, that got the blame, and that somebody (as real to him as hand or foot) was not the sufferer himself, but an evil spirit lurking around the corner with nothing better to do than to take delight in hurting one's head or lighting fires within one's frame. The cure? Anything that would drive away the torturing demon.

Now devils, like other folk, should resent the disagreeables, so the man for the occasion—the healer—the medicine man of the tribe—logically assailed the eyes of the evil spirit with his horrid appearance and his dreadful antics, battered the spirit's ears with the noise of his tom-tom, provoked the spirit's nostrils with the odors from decoctions of noisome things, and befuddled the spirit's mentality with puzzling jargon. The malevolent spirit often (though sometimes with due deliberation) betook himself elsewhere. At any rate, in many cases, the headache passed, or the fever subsided, and the medicine man received the credit, with, incidentally, some remuneration for his valuable services. That he was not always successful was no matter of wonder. Some spirits must be especially stubborn. Moreover, had he always effected a cure there would have been, there and then, an end to the evolution of therapeutics, there would have been but one kind of medicine man—and this story would never have been written. Paradoxically, progress in cures was the outcome of failure to cure, and failure to cure meant, likewise, further study and revision of ideas of ailments.

And it came to pass that the chief of the tribe fell sick after a feast, the medicine man was called and did his best but without results. The sick man grew worse rather than better. By a stroke of ill luck, the man of medicine had more than one failure to his credit. The chief was told of a healer with ascendant star, in a neighboring tribe. The latter was sent for. Medicine Man Number Two consulted with Medicine Man Number One—*the first consultation*. Strange, their ideas and methods agreed—their horribles were identical. It was evident that the resources of the old school had been exhausted so far as the case in hand was concerned. But the reputation of all medicine, as well as the lives of these medicine men, were in danger. Something must be done. A cauldron for incantation containing a decoction of loathsome things—dung, toad's eyes, snail slime—was handy. Why not drench the evil spirit from the chief? It was a daring venture, but it worked like a charm—better than a charm, for charms had been tried. The noisome beverage was hardly down before it was up, and with it the undigested meal. A new era in medicine had set in—the age of drugs.

The new field was practically unlimited. The animal, vegetable and mineral kingdoms were ready to be ransacked for new cures as fast as the old ones failed. New drug after new drug had its day for hundreds of years until, from mandrake to musk and from calomel to cod-liver oil, they were gathered from the ends of the earth. They filled the bottles and stuffed the drawers of the apothecary from floor to ceiling. It's a long and interesting story. The magic of the old order clung for a long time to the new, and materials for pellets, powders and

potions worked more wonderfully as they were gathered in witching hours, in the appropriate phase of the moon or in magical neighborhoods. The drugs that might be (and have been) tried were legion, and when they failed singly, there was always the possibility that a new combination of them would prove effective. If one would not cure, certainly a half dozen of them, carefully compounded, would do the work. The physician and the apothecary, as well as the patient, honestly believed they would produce a cure, and often, as in the days of the noisier and more spectacular medicine men, the sick got well. In fact, some of the means used were genuinely helpful and in process of time have proved their worth.

And a new magician arose, even in the nineteenth century, who said, and doubtless believed, that he increased the potency of a drug by dilution—until a drop of the substance, as formerly dosed, added to a pail of water was pronounced more powerful for good (it was certainly less potent for harm) than the unsublimated substance. The "homeopathic" dose cured—on many occasions and it had always the quality of harmlessness.

The end of drug cures is not yet, for there was some small good in the long line of emetics, cathartics, diaphoretics, diuretics, antispasmodics, hypnotics, emollients, digestants, demulcents, alteratives, etc.,—in large or in small dose, singly or in combination, concentrated or dilute, applied externally or taken internally, sold in plain packages or in containers of attractive shapes with costumes of many designs, prescribed by physician or by pharmacist, advised by their recipients or advertised in the daily news.

Tó return again to earlier times—the chief was sick. He had a splitting headache for which neither incantations nor drugs availed. Something new must be tried. A medicine man of rare imagination (imagination has been the source of all scientific achievement) suggested that the reason why the evil spirit did not avaunt was that he had become imprisoned in the royal skull. Or maybe there was another more scientific theory. Had not the head of the head of the tribe bothered him since his last battle, in which he was banged on the cranium with a stone axe? It was a bold undertaking, but there is ample evidence that at a most primitive time the operation of trephining the skull, with implements of stone, was done and done successfully—with survival and with cure. Surgery was begun, and with ups and downs has reached its present state of development. The modern surgeon is sometimes daring, but by no means ever so fearless as he, who, in remote time, without anesthetic, opened the skull of his patient with a sliver of flint.

The blood was noted by physiologists of early days as something necessary to life and, hence, of much concern for health. They named it "vital fluid." There might be too little of it, they thought, and maybe there might sometimes be too much of it. Did not a flushing of the face and beating of arteries of the neck accompany headaches, apoplexy and fevers? Then there was phlegm. It needed no anatomizing to discover that there might be too much of that. A cold was nothing more nor less than an excess of this "humor." Then bile—there must be something very significant about this, for often there was "too much" and it "came up." We were "bilious." Or maybe it turned dark when we were blue or we were blue because the bile was not yellow bile but "melancholy" or black bile, for melancholy means black. "Sanguine" (too much blood), "phlegmatic" (too much phlegm), "bilious" (too much bile), "melancholy" (too much black bile)—how familiar the terms, though they are thousands of years old and have been the basis of theories and cures galore! In how many of us are those four "humors" so nicely proportioned

that we are neither too melancholy, too bilious, too phlegmatic or over-sanguine, but just "good-humored"?

The cure by drugs fitted well into this old Greek scheme of human ills. Biliousness, in particular, still has such remedies, which work as magically for this nomenclature as under the less ancient and less elegant explanation of constipation. There were medicines to "dry" the blood and to "thin" the blood, but to reduce its menacing quantity and to rid the body of bad humors, drugs were too slow and uncertain. It seemed vastly more expeditious to "open" a vein. Phlebotomy, with or without accessory helps, became a cure for everything. For many centuries everybody was "let blood" on general principles, every spring, and, for what ailed them, at all seasons.

Far back—even before man's emergence from lower animal forms he found it "helped a lot" to rub an injured part of his body. Indeed, to "scratch himself" against a tree was an age-long animal practice, but to have some one stroke an injured part or to rub one's back or one's limbs when one is tired is better than medicine. Massage, gentle or severe, stroking, rubbing, beating, slapping, has, for thousands of years, had its ups and downs as remedies for all manner of ills, and for many of our ailments, such manipulations and passive exercise have been very helpful. Napoleon found mechanical therapeutics to his liking, and the Moslem masseur he discovered in Egypt earned his board and keep, for Napoleon kept shouting to him, "Rub harder, harder, as if you were rubbing an ass!"

Cures by exercise (not done by proxy) have also flourished and still do so, from Delsartian waving of arms to the lifting of heavy weights. "Systems" of exercises, with and without apparatus, each guaranteed to cure all ills and raise man to perfection have had their day and ceased to be.

To return to the beginning of another species of cure. Man, or some of him, became so matter of fact that, instead of blaming the spirits for his ills, he conceived that he himself (being possessed of "freedom of the will") might sometimes bring upon himself his own ills. His stomach was a frequent source of bother. Was it altogether to blame? We, like cattle, have grinding teeth—why, then, it's evident we should do best as vegetarians. But having pointed canines, like those of the dog, maybe it is meat we need. But do not our chisel-shaped incisors serve best for fruits? Maybe we were meant for that diet. Cereals, vegetables, meats, fruits, have all been classified according as they affect our "humors"—as to whether they are too "moist" or too "dry" or too "hot" or too "cold" for the good of the consumer. It is all set down in those interesting old health books with such charming titles as: "The Castle of Health," "The Mirror of Health," "The Highway of Health," etc. Raw food faddists, the cooked food faddists, the masticators, the one-mealists, the two-mealists, the grape cultists—the dietary changes have all been vigorously rung.

And drinks! The taking of wine for the stomach's sake is older than Saint Paul; rock and rye were said in their day to have done wonders, while even water, "mineral" or plain, applied internally or externally, has had endless cures to its credit. Possibly these latter reached their height of fashion in England and Germany before the war.

A cold bath has an undoubted effect. We gasp, we shiver, our heart beats faster, we feel different. May not the cold bath be what we need for things that ail us? Yes, here is a list, taken from a popular book of the eighteenth century, of some of the ailments it will (or once would) "cure."

Convulsions	Rupture
Vomiting	Suffocation
Rickets	Sciatica
Gravel	Rheumatism
Insomnia	Torpor
Ague	Tetanus
Lethargy	Scorbutus
Loss of appetite	Vertigo
Pain in the back	Varicose ulcers
Pain in the joints	Headaches
Atrophy	Sore eyes
Epilepsy	Hydrophobia
Incubus	Surfeit (at the beginning)
Leprosy	

Why seek further for a cure? There are volumes that tell of hydrotherapeutics in other forms—from walking in the dewy grass at dawn to a hot tub bath at bedtime.

Light seems essential; heat is necessary to life. Why not cures of disease by sunshine, by electric-light baths, by red lights, blue lights, green lights? They all have "cures" to their credit, as has electricity in all its forms—galvanic, faradic, static, high frequency, "animal magnetism," with that weird personality, Mesmer, as the outstanding, picturesque apostle of such treatment.

The first medicine man made music over the sick. So ever since, there has been reversion to music cures, and even of late, following the wholesale methods of the age of machines, there have been established music clinics where one may be soothed or stirred, changed, certainly for the time being, by floods from "music's golden sea."

But maybe it's the air that ails us? It was the "mala aria" air (bad air) that once caused malaria. At any rate, a "change of air" may help us—Egypt, the Riviera, Switzerland, New Mexico, California. There was something in this for some people, but alas, as Mark Twain so aptly put it, for most of us, "climate is our human environment." The best climate is bad without congenial company of our kind, and this is not always forthcoming. But if it's not the air, it's your method of use of air. Have you tried Ben Franklin's air bath—sitting in your skin for a season before you dress? Or have you done breathing exercises? These are (or were) good for all your ills—if you learn the prescribed technique.

But if air itself is not bad, what carried contagion? It was long ago guessed that plagues were conveyed, not so much by the air, as more directly from sick to well. The leper and his like were called unclean and were driven apart. There was a mysterious something that was conveyed by humans themselves and which might cling to human habitations. Long before the germ of tuberculosis was discovered, the composer, Chopin, dying of consumption, was obliged, by order of the local authorities, not only to repaper but to replaster a mansion from which he had moved. The plagues from the hand of God were finally discovered to be plagues from the hand of man. The microscope has revealed the thing that often ails us and has made us blush over the absurdity of many once-believed-in means of cure.

With all this kaleidoscopic evolution of notions of disease, from possession by a demon to infection by fungi, no universal cause and no universal cure has come to hand. Perhaps, after all, there is no such thing as disease. Haven't we been chasing a will-o-the-wisp? Haven't we been merely imagining bodily distress and merely "seeing things" when we look at a cancerous stomach or a lung riddled by tubercle bacilli? There are "healers" who take this view and work their "cures." Though their practices are less spectacular, they remind one strongly of the first medicine man mentioned in this essay. Has the race, or a part of it, entered upon its second childhood?

All these bewildering myriad cures resulted, as mentioned previously, from failure to cure, but back of this was the fact, now well known, that the human body has the ability, if not too hard hit

by accident or disease, of getting rid of the cause of its ailment and of repairing (within limits) the damage that has occurred. In other words, it possesses in large degree the power of curing itself. So, when treated (and sometimes in spite of treatment) it recovers, and hence the method used seems to cure. When, however, the powers of resistance and of repair are overwhelmed, as comes sooner or later with all of us, nothing can prevent dissolution, and any and all attempts at cure, used on this occasion, must suffer in repute. A few such failures sealed the doom of remedies whose names have become legion.

Even had there been but one cause of sickness, many means of healing would have been tried, but as we now realize, there are many causes, most of them born of our own personal or communal ignorance or perversity and capable of removal or prevention.

During the long ages when the various causes of disease and the real nature of their cure were a mystery, the long experimentation with means and methods has led to the final sifting out of a few (a very few) physical or chemical agencies which, in certain instances, really are a help. The latest medicine man, looking over the list, is able to select such of these ways and means as have proven of benefit and apply them when and where they may possibly be of service to the body in its struggle back to health.

From the bold and ignorant person, who, because a few patients happen to get well during the administration of one means of cure, applies that method of treatment indiscriminately to all who hopefully seek his aid and pay his price, to the physician who, through long and patient study, learns what is now known of the causes of sickness and who conscientiously and cautiously commands the few resources which can be selected from the age-long therapeutic rubbish heap, from word of hope and hand of message, from quinine and morphine to insulin or antitoxin or the use of the surgeon's knife, the gap is as great as from the stone age to the present.

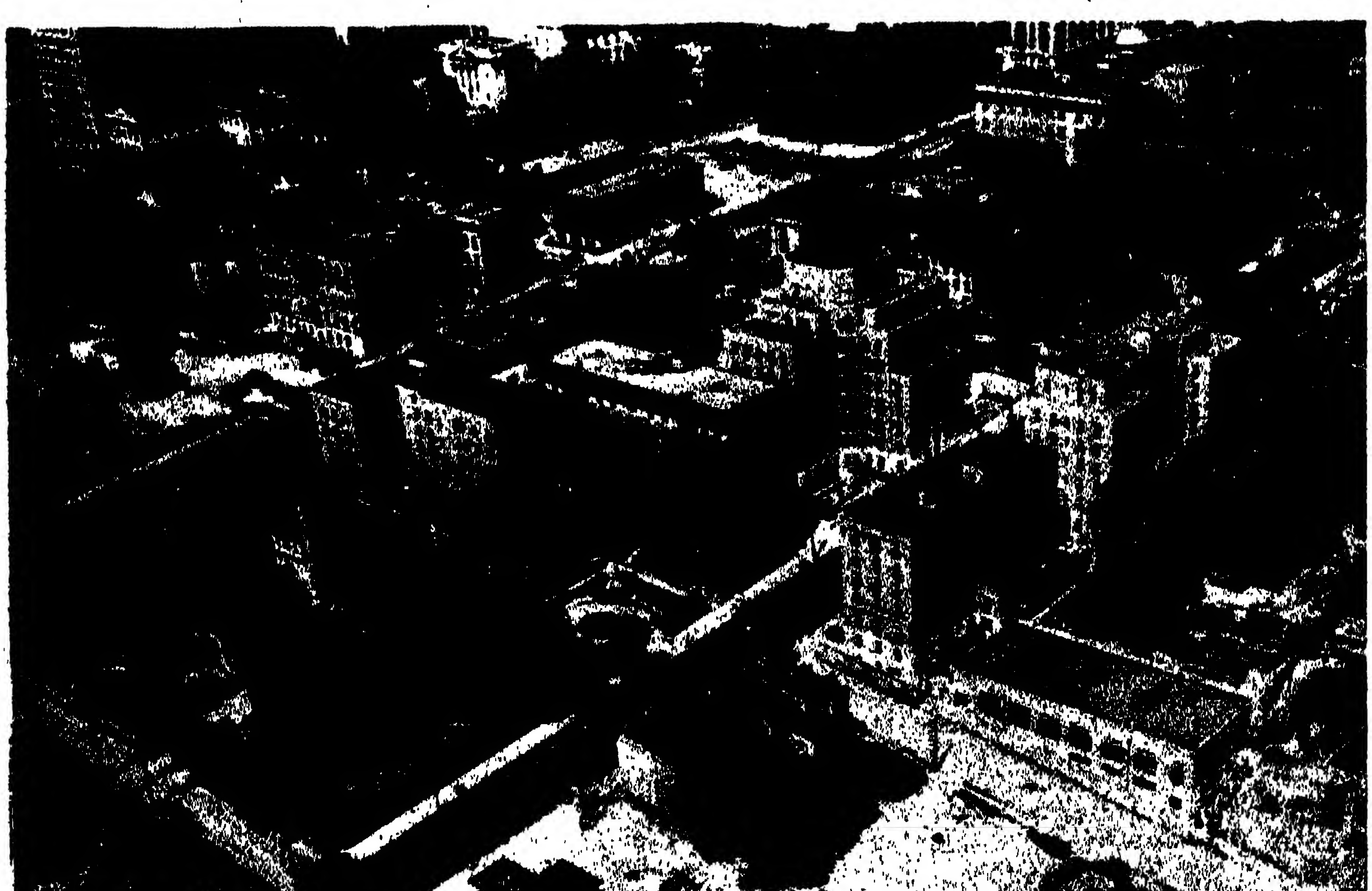
We have progressed mightily in the knowledge of the causes and of the true nature of the cure of disease, but the most important lesson to be learned from the experience is the old one—that an ounce of prevention is worth more than a pound of treatment and that we are wise when we learn the laws of health, personal and communal, and try to obey them.

Instead of depending on cures for the results of bodily sins, we may well follow for the rest of our days the suggestion of the wisest of mankind and "despise no new Accident in our Body," for "there is wisdome in this, beyond the Rules of Physicke: A Man's own Observation, what he find Good of, and what he finds Hurt of, is the best Physicke to preserve Health."

When we are lost in the maze of human experience and are unable to decide what is hurtful or helpful we do well to follow Francis Bacon's further advice and "ask Opinion" of the new and better medicine man who is acquainted with the modicum of good in the many systems of healing that have come and gone, who is wedded to no one cure (as he sees no one cause) for human ills and who is as interested in helping us to work out our bodily salvation and to lead a healthy life (in so far as our heredity and past shortcomings will permit) as he is in helping us out of scrapes due to our carelessness or ignorance.

AN AERIAL VIEW OF RICHMOND'S CIVIC CENTER

THE REGISTRATION, GENERAL SESSIONS AND THE SCIENCE EXHIBITION WILL BE IN THE MOSQUE, NEAR THE CENTER OF THE PICTURE.



AN AERIAL VIEW OF A PART OF THE MEDICAL COLLEGE OF VIRGINIA

SESSIONS OF SEVERAL SOCIETIES WILL BE HELD IN THESE BUILDINGS.

THE PROGRESS OF SCIENCE

THE VIRGINIA MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

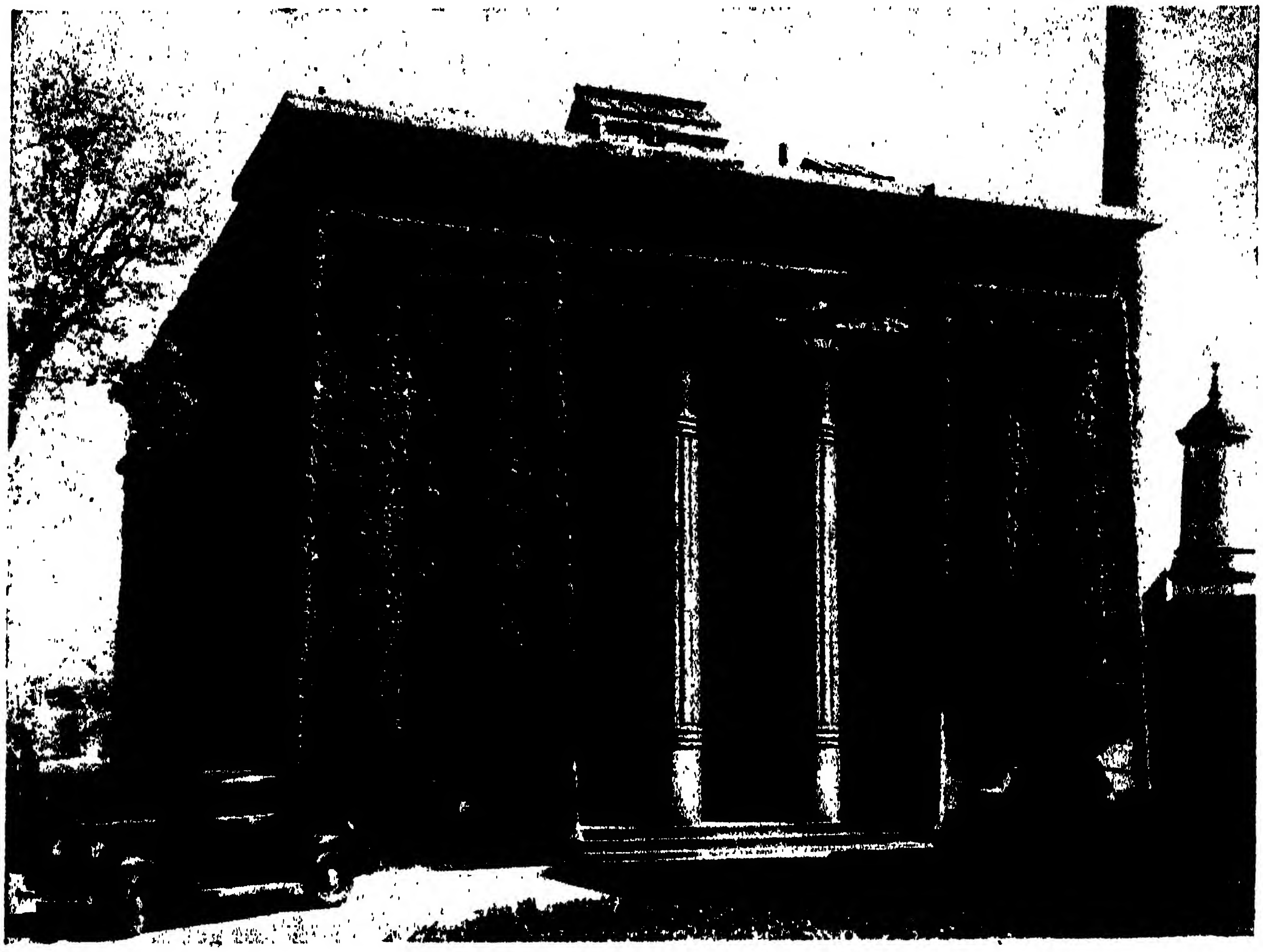
FROM December 27 to 31, inclusive, the American Association for the Advancement of Science will hold in Richmond its first meeting in Virginia. A year ago the association held its winter meeting in Indianapolis, Indiana; its summer meeting, last June, was held in Ottawa, the capital of Canada; and next summer the association will meet in Milwaukee, Wisconsin. Thus the meetings of the association are held in important cities from Minneapolis to New Orleans, from Boston to Los Angeles.

There are two important reasons for holding the meetings of the association in various parts of the United States and Canada. The first is to carry the inspiration of great gatherings of scientists to all parts of these countries. The second is to enable the scientists of one section after another to meet with their fellow scientists without great expense in time and money for travel.

It is necessary to attend a meeting of the association in order to see science on the march and to feel the warm glow of its spirit. Immediately after next Christmas trains from the Southeast and the South as far west as Texas will be crowded with scientists bound for Richmond; and trains from snowy New England and Canada and from the frozen Middle West will be carrying other scientists to milder Virginia. Some of them will be specialists in the physical sciences—mathematics, physics, chemistry, geology—and the fields of others will be the biological sciences—zoology, botany, medicine, agriculture and all their various divisions and branches. Still others on these Richmond-bound trains will be interested in man: the anthropologists will be interested in him as the product physically, mentally and culturally of a long evolution; the historians and philologists will be interested in the story of his achievements as preserved in his written records and his speech; and the psychologists and educationists will be interested primarily in the nature and cultivation of those marvelous faculties of his which most distinguished him from the remainder of living organisms. The interests of the scientists who will attend the meeting of the association in Richmond in December will be as broad and varied as science. Not only will the fifteen sections of the association hold scientific sessions on nearly every aspect of science, but approximately fifty affiliated special scientific societies will also meet in Richmond.

As the scientists approach Richmond they will not be listening to orders from bosses as to what they should think and say; they will not be anxiously considering the effects their words may have upon special groups; they will not be jockeying for position and preferment. Their rivalries will be in making discoveries and placing them at the service of science and society. They will be happiest when they can give most to their fellow men. In their actions they will illustrate attitudes that are greatly needed for the progress of civilization.

Richmond is a lovely city just where the softer life of the southland rubs elbows with the greater drive and efficiency of the north. It is rich in historical associations. Such names as John Marshall and Lee and Poe give it distinction. The afterglow of a rapidly vanishing aristocratic age still hovers over it. Almost at its door restored Williamsburg brings down the romantic past to the more practical present. The citizens of Richmond are noted for their friendliness and hospitality, and they will make up in warm welcome and attention to the comfort of visitors what



THE EGYPTIAN BUILDING OF THE MEDICAL COLLEGE OF VIRGINIA
THIS BUILDING, BUILT IN 1845, IS ONE OF THE OUTSTANDING EXAMPLES OF EGYPTIAN ARCHITECTURE IN AMERICA.

their city lacks in the facilities of larger centers of population. The visiting scientists will retain memories not only of their inspiring meetings but also of a comfortable, leisurely way of living that still lingers here and there in the Southland. And, reciprocally, Virginia and all its neighbor states will throb with the strong pulse of science that is working revolutions in the life of those areas as well as in that of the remainder of our country. If this should not happen, the Virginia meeting will not fulfil the purpose of the association in holding it in Richmond.

Not all the sessions of the meeting will be devoted to technical papers. The presidential address by Dr. George D. Birkhoff, of Harvard University, will be on the subject "Intuition, Reason, and Faith in Science." Sir Richard Gregory, the distinguished editor of *Nature,* will deliver an address at a general session on the interrelations between science and society. For sixteen years the Society of the Sigma Xi, a great organization of "companions in zealous research," has provided a program for the second evening of the annual meetings of the association. This year Dr. W. F. Durand will be the speaker on "Modern Trends in Aviation." For three years the United Chapters of the Phi Beta Kappa have sponsored addresses by eminent scholars. The fourth lecture in this series will be delivered by Frank Pierrepont Graves on "Is Education a Science?" In addition to these regular features of the programs, there will be numerous addresses on many fields of science that will be of interest to the general public. Perhaps none of greater

importance will be presented than those in the symposium on "Mental Health." The medical profession and society are only now realizing clearly that our minds are subject to about as many disorders and quirks, most of them not serious, as are our bodies, and that they deserve at least equal competent attention. In this symposium organized by the Section on the Medical Sciences the association is making a contribution to the welfare of society in a new field. It is but one of many problems challenging the association.

F. R. MOULTON

SIR RICHARD GREGORY

AMERICAN culture and learning have been enriched through visits to this country, from time to time, of eminent English men of science. In surprising number, both the men of England who are foremost in scientific research and those who have thought deeply about the ultimate values of science possess the power of lucid exposition. Not a few English scientists who have important discoveries to their credit and others who are at home in philosophical discussion talk and write about their work, if occasion calls for it, in a delightfully simple and graphic way. In consequence, such men command large and attentive audiences among Americans whenever a lecture by one of them is announced.

In December next, upon invitation of the Carnegie Institution of Washington, a member of this distinguished group, Sir Richard Gregory, is coming to America to deliver the fifth of the Elihu Root lectures—a series established by the institution in honor of Mr. Root, a trustee from the beginning and chairman of its board during the last twenty-four years of his life.

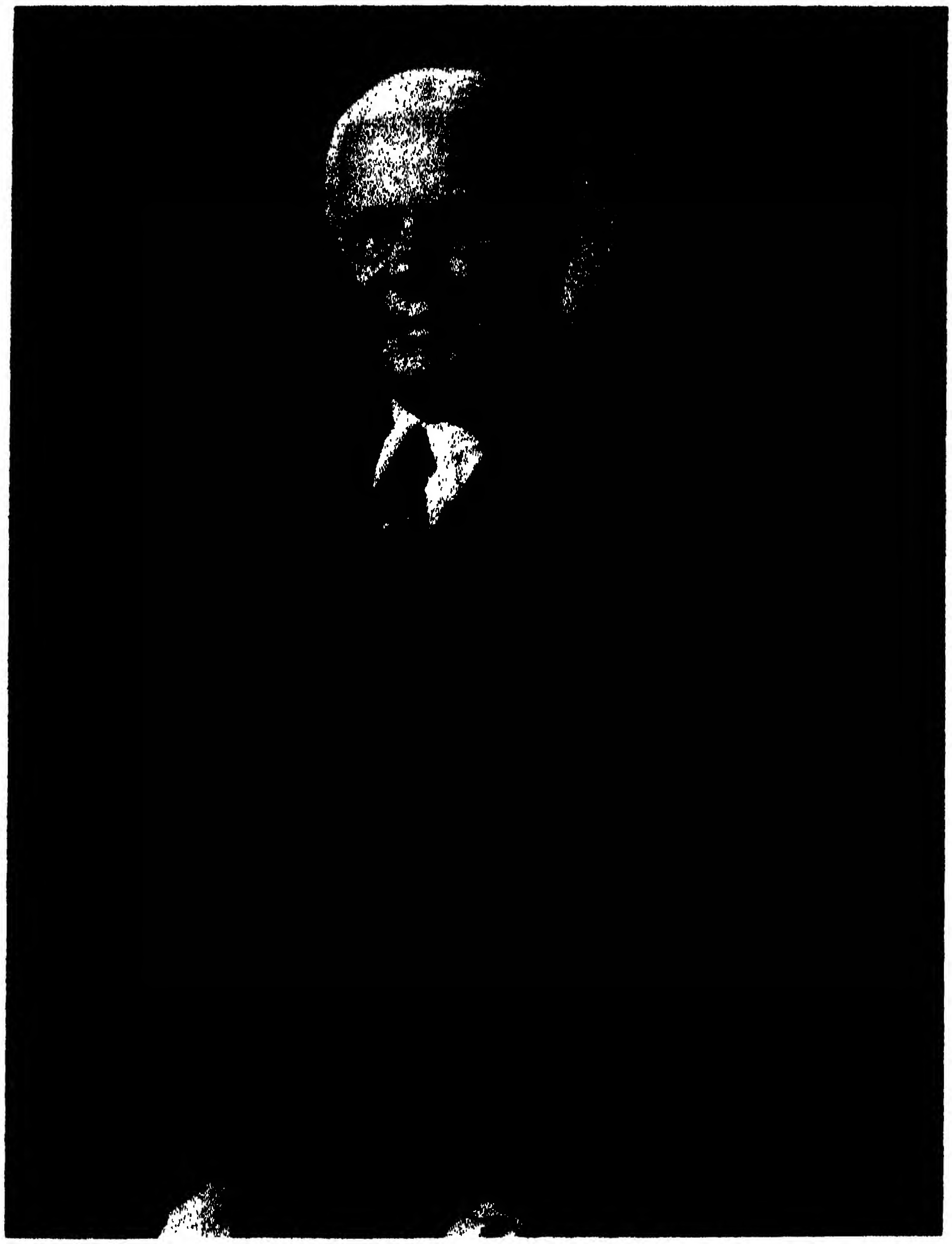
Sir Richard is widely known among American scientists through his editorship of *Nature,* an English journal, with a large American circulation, which has become an international clearing house for preliminary announcement of scientific researches. For forty-five years he has served this journal, first, as assistant editor and, since 1919, as editor. During the period he has contributed to the journal literally thousands of columns of vigorous editorial comment and observation.

Richard Arman Gregory was born in Bristol in 1864. His father was a shoemaker by trade but a poet by nature and the author of several volumes of beautiful verse. His grandfather was for sixty years a lay preacher of the Wesleyan Church at Bideford, Devon, where a tablet is erected to his memory. Sir Richard Gregory said on one occasion: "My grandfather preached the Gospel of Christ; my father preached the gospel of socialism; and I preach the gospel of science; but the ethical principles of all three are the pursuit of truth and righteousness for the improvement of man and society."

After leaving school at twelve years of age, Sir Richard became in succession a newspaper boy, page boy, machine boy in a printing office and apprentice to the boot and shoe trade. Through his studies before and after factory hours, he came to the notice of the head master of Clifton College, on the outskirts of Bristol, and was given by him a minor post in the physical laboratory of the college.

After leaving the college, he became science instructor at H. M. Dockyard School, Portsmouth, but returned two years later to become research assistant to the great astronomer, Sir Norman Lockyer, who in 1868 discovered in the sun the then unknown gas, named by him helium, which was not identified on the earth until twenty-six years later. In 1893 Sir Richard became associated with Sir Norman as assistant editor of *Nature,* succeeding him as editor in 1919.

Sir Richard Gregory and Mr. H. G. Wells were fellow students at the Royal College of Science, London, and their friendship has remained close and un-



SIR RICHARD GREGORY

broken. They had won studentships at the college in open competition and were to be trained there as science teachers. Mr. Wells has described the aims and hopes and struggles of himself and other students at the college in several of his works, such, for example, as "Love and Mr. Lewisham," and particularly in his "Experiment in Autobiography." Even in those days Mr. Wells showed the distinctive literary powers which have made him preeminent among modern writers, and became the first editor of the *Science School Journal,* with Sir Richard Gregory as one of the contributors.

In the same year, 1895, that Mr. Wells entered the field of imaginative literature with "The Time Machine," the main idea of which he had used in a story in the college magazine while a student, he collaborated with Sir Richard in a small volume entitled, "Honours Physiography," for which each of the authors received the modest sum of fifty dollars.

Sir Richard's early contacts with social reformers and with the stern reali-

ties of life and labor made him familiar with the human aspects of applied science as affecting industry. This probably accounts for the attention given in *Nature* during his editorship to the social relationships of science. He holds that as science is responsible for the industrial developments and economic changes which have caused violent disturbances in the social structure and provided also the means by which civilization may commit suicide, it has a duty to guide the human race to the wise use of the powers it has created.

In line with this conception of the place and purpose of science, Sir Richard declares that the day when men of science were expected to keep within the bounds of their laboratories and any attempt to enter social fields was resented as an intrusion is past. "Fifty years ago," he says, "science had to establish its rights to the pursuit of truth in matters affecting traditional belief, but to-day it is the state and not the church which would suppress intellectual freedom."

Because of his condemnation of actions which destroy this essential condition of progressive knowledge and of the persecution of scientific workers for racial reasons or because they are unwilling to be fettered by political chains, several months ago the minister of education in Germany issued an order that *Nature* should not be taken officially in the universities and public libraries of that country.

In the forthcoming institution lecture, Sir Richard will discuss "Cultural Contacts of Science." In this address he will deal chiefly with the influence that science exerts upon cultural values rather than with the services rendered to communities by the utilitarian uses to which scientific knowledge is put. Carnegie Institution will publish the lecture, so that all who wish a copy may obtain it.

After filling his institution engagement, during the short time Sir Richard is able to be away from England, he will deliver a few lectures in this country.

FRANK F. BUNKER
THE CARNEGIE INSTITUTION
OF WASHINGTON

THE NEW ENGLAND HURRICANE OF SEPTEMBER 21

THE tremendous rise of water or "storm wave" that accompanied the hurricane was probably totally unexpected by most residents of the southern New England coast. It was this inundation, rather than the wind, which really caused the great loss of life and enormous damage to property. However, the storm wave has long been a well-recognized feature of hurricanes. Tannehill, in a recent book on hurricanes,[1] devotes an entire chapter to the phenomenon. He states that "more than three fourths of all the loss of human lives in tropical cyclones has been due to inundations. The rise of the sea over low coastal areas not subject to overflow by ordinary tides is sometimes sudden and overwhelming and in some situations there is no escape."

How applicable the above quotation is to this particular storm! But why was the region of severe inundation confined to a stretch of coast between Martha's Vineyard and the central part of Long Island? As Tannehill further states: "The true storm wave is not developed unless the slope of the ocean bed and the contour of the coast line are favorable. Like the gravitational tide, it reaches its greatest height in certain situations. If there is a bay to the right of the point where the cyclone moves inland, the waters are driven into the bay. With a gently sloping bed, the water is piled up by resistance and becomes a great wave or series of waves which moves forward and to the left, the principal

[1] I. R. Tannehill, "Hurricanes." Princeton University Press, Princeton, N. J., 1938.

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THE SEA IN ACTION AT WOODS HOLE

UPPER: SURF BREAKING OVER THE TOP OF THE SEA WALL. LOWER: WRECKAGE TOSSING IN THE WAVES. THE BUILDING IN BACKGROUND AT THE UPPER LEFT IS THE WOODS HOLE RESIDENCE HOUSE OF THE U. S. BUREAU OF FISHERIES STATION.

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MAIN STREET OF WOODS HOLE LOOKING EAST NEAR HEIGHT OF STORM

SHOWING THE CLUBHOUSE OF THE MARINE BIOLOGICAL LABORATORY AT HIGH WATER FROM BENEATH WHICH TONS OF EARTH WERE WASHED. IN THE MAIN BUILDING, NOT SHOWN, ACROSS THE STREET TO THE WEST, THE WATER ROSE TO A HEIGHT OF FOUR FEET IN THE GROUND FLOOR, CAUSING AN ESTIMATED DAMAGE TO APPARATUS ALONE OF ABOUT $20,000.

inundation usually taking place on the left bay shore. Great storm waves which have taken an enormous toll of human lives have, so far as records are available, occurred in nearly every case in a situation of this kind."

The path of the storm, as Dr. Gardner Emmons notes in commenting on the work of Tannehill, was to the west, that is to the *left,* of Buzzards Bay and Vineyard Sound. In addition, as is well known to oceanographers, the ocean bed to the south has a comparatively gentle slope. Thus the necessary conditions for the development of a storm wave are fulfilled. As Tannehill points out, the coincidence of the arrival of the storm wave with the time of the maximum height of the gravitational tide produces unprecedented high water.

Although present residents of the region have no recollection of any similar catastrophe, Mr. Trayser, in a recent issue of the *Falmouth Enterprise,* records three previous occasions when hurricanes created tidal waves in Buzzards Bay: namely, on August 14 or 15, 1635; September 23, 1815; and in 1869. In commenting on the subject of earlier hurricanes in the region, Dr. Alfred C. Redfield, of Harvard University, in a letter to one of the editors, writes: "You may be interested in information that I draw from my family archives for an account of a similar storm which crossed New England in 1821 and which had a profound, and fortunately constructive, effect on the advancement of knowledge about tropical hurricanes and on meteorology in general.

"My grandfather records, in his 'Recollections,' that on the evening of September 3, 1821, while his stepmother was lying on her deathbed, a gale, short in duration but terrific in violence, passed over Connecticut. For many years thereafter it was spoken of as the 'great September gale.' About a month after this, his father, William C. Redfield, visited Stockbridge to carry to his wife's parents

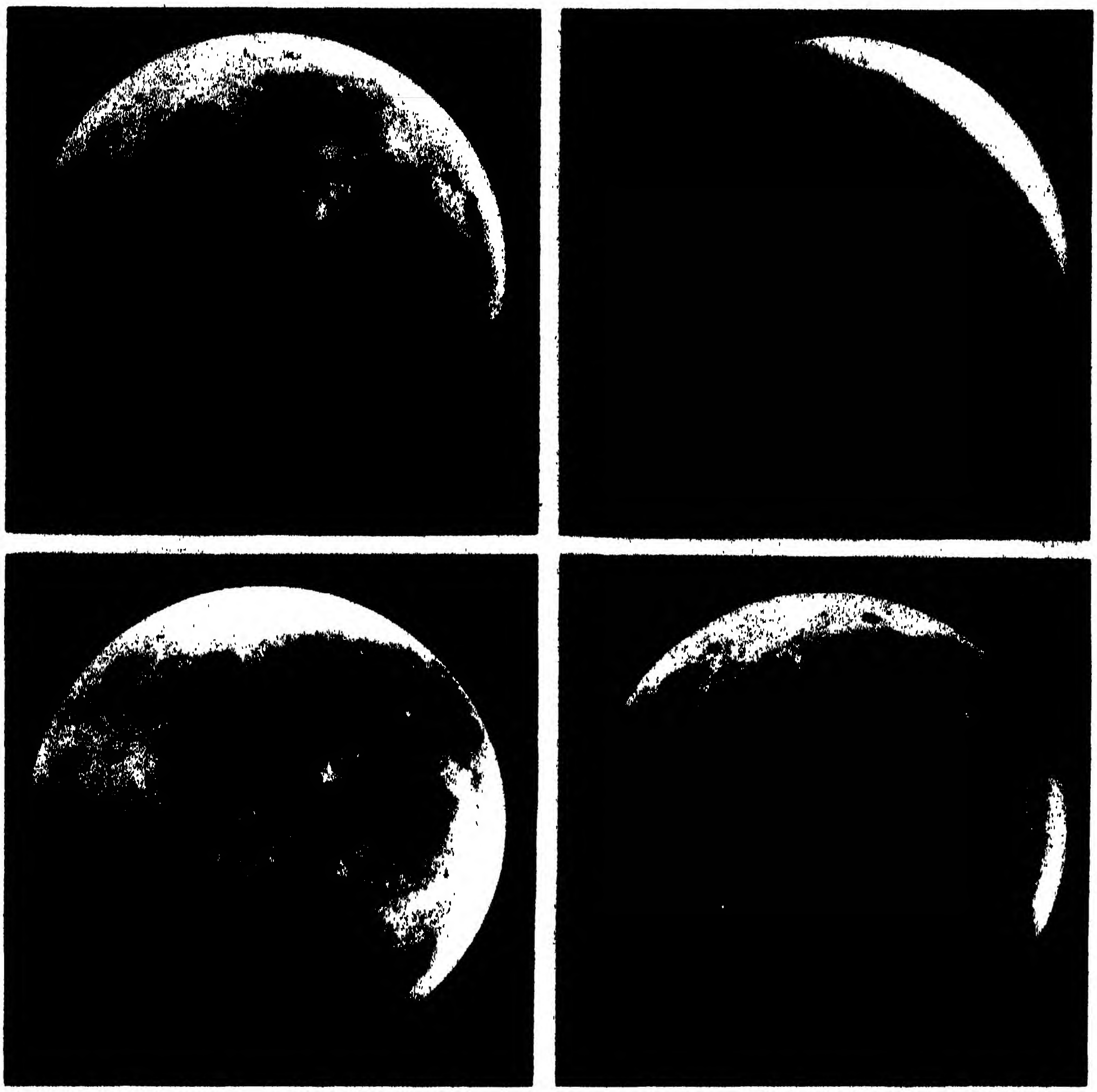
some of her belongings and to give the sad history of their daughter's last illness. The journey of seventy miles between Cromwell, Connecticut, and Stockbridge was made by wagon and occupied two days. As he drove along, he observed that at Middletown and Cromwell the wind had been from the southeast and the trees lay prostrate with their heads northwest. On reaching Berkshire he was surprised to see that they lay in the opposite direction, and on conversing with the residents of that region, he was astonished to learn that the wind, which at 9 P.M. had been from the southeast at Cromwell, had been in Stockbridge from the northwest at precisely the same hour. These facts at first seemed to him irreconcilable. It did not appear to him possible that two winds of such violence should be blowing directly against each other at the distance of only seventy miles. The only explanation of this paradoxical phenomenon was one which he was then led to accept hypothetically, but which he afterwards confirmed by years of observation and the collection of innumerable facts and which established the circular movement of the wind in great storms. The *American Journal of Science and Arts* of April, 1831, published the detailed record of the course of the great September gale of 1821, based on reports obtained from at least forty places, including ten ships at sea. The earliest trace of the hurricane was from off Turk's Head in the West Indies. The storm crossed over the continental coast south of Cape Hatteras and veered to the northeast, following the coastline closely, its center apparently passing across the mouth of Delaware Bay and hitting the New England coast in the neighborhood of Bridgeport. It passed across the Connecticut Valley and was last observed in northeastern Massachusetts. In New York, at the time of low water, the wharves were overflowed, the water having risen 13 feet in one hour. At Boston the gale commenced at 10 P.M. but does not appear to have been severe. At the time the storm was raging with its greatest fury in New York, the citizens of Boston were witnessing the ascent of a balloon, and the aeronaut met with little or no wind.

"Similar records obtained following two severe northeast storms, which were felt in New York City in 1830, showed them to have a similar course and character, though they followed the more usual route to the south of New England's coast, and led to the first published account of the cyclonic nature of such hurricanes and the plotting of their courses and rates of progression. These studies were continued and amplified by observations of Reid at Bermuda and Piddington and Thom in the Indian Ocean and not only led to the establishment of definite rules for handling vessels on the approach of a hurricane, rules which still appear on the pilot charts, but also laid the basis for the understanding of the cyclonic disturbances which characterize the weather in temperate latitudes and for the synoptic method for analyzing the movements of air masses."

THE LUNAR ECLIPSE OF NOVEMBER 7

THE sun had not yet set and the moon was in the umbra of the earth's shadow when the moon rose at Washington on the afternoon of November 7, at 4:56 P.M., Eastern Standard Time. According to the Ephemeris, the moon was scheduled to begin to emerge from the umbra at 6:07½, to leave the umbra (complete shadow) at 7:12, and to leave the penumbra (partial shadow) at 8:14 P.M. Sunset was at 5:02, and the end of evening twilight at 6:23.

The Naval Observatory's 40-inch reflecting telescope, with a focal length of



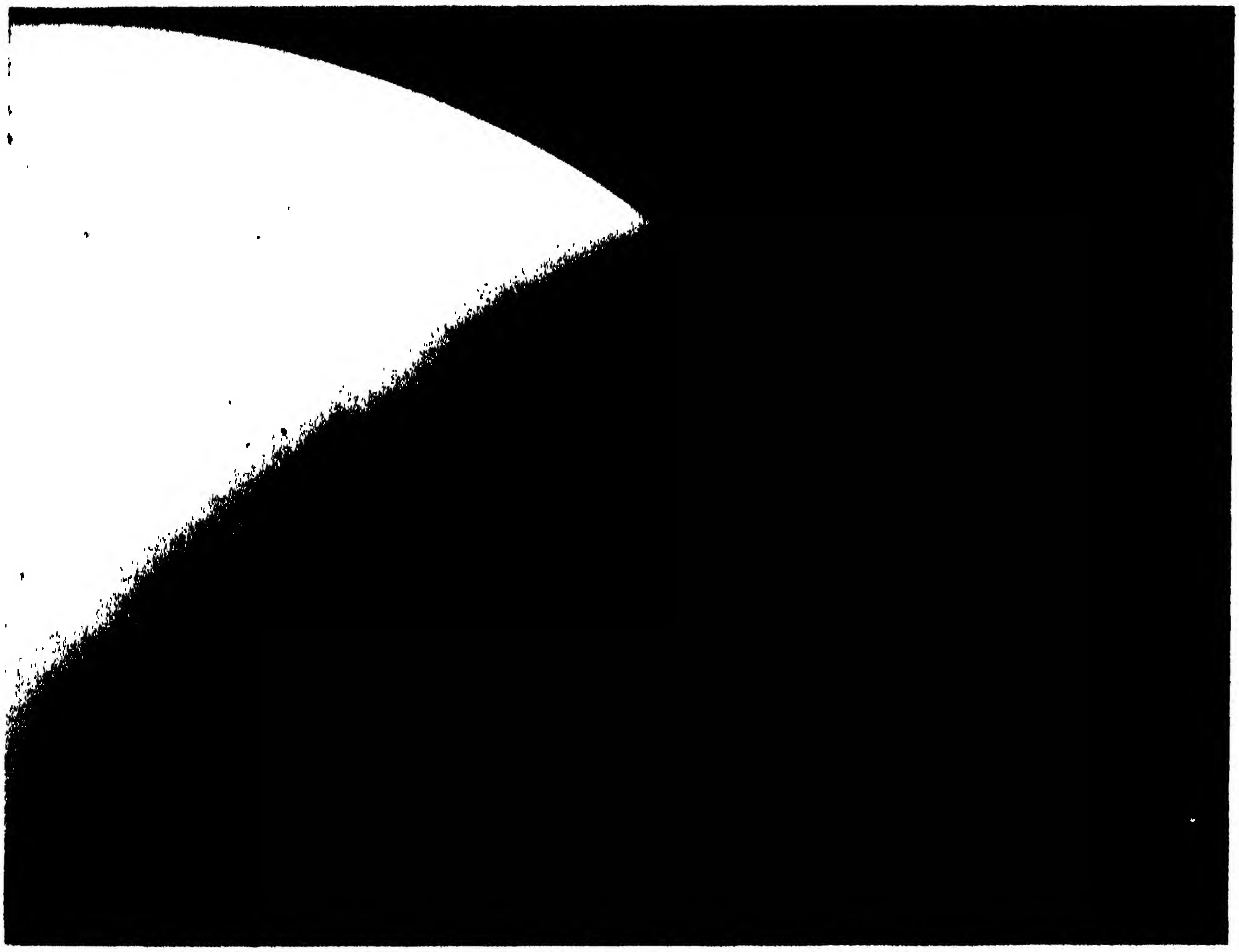
THE MOON EMERGING FROM THE SHADOW OF THE EARTH
(LEFT TO RIGHT) AT 6: 14 P.M., 6: 45 P.M., 7: 02 P.M., 7: 16 P.M., E.S.T.

about 23 feet and operated with a relative aperture of 1 : 10, was focused on a star and made ready to photograph the eclipse.

The first glimpse of the totally eclipsed moon, shining dimly in the east from the illumination of a rosy ring of terrestrial sunsets and of the pearly light of the solar corona, was obtained about 5 : 26. With the fading of twilight it became more and more visible, and more colorful—like a slightly tarnished, relatively new penny.

The first of six exposures using the new Kodachrome cut film was made at 6 :06, just before the instant of the beginning of the moon's emergence from the umbra. A number of exposures for black-and-white negatives were made on Agfa Isopan films and on Kodak Panatomic plates. The last exposure was made at 7 : 16, through a break in the clouds. Later in the night, the bright silvery moon rode high in the sky, causing one to marvel at the great range through which its illumination had changed within a few short hours.

A sequence of photographs showing



THE PLANET URANUS NEAR THE ECLIPSED MOON
AS SEEN FROM WASHINGTON, D. C., AT 6: 32 P.M., E.S.T., APPEARING AS A WHITE DOT IN THE LOWER RIGHT-HAND CORNER. THE PLATE WAS EXPOSED 15 SECONDS.

the emergence of the moon from the dark shadow of the earth was prepared from the negatives which had been exposed, for durations of the order of ½ second, at 6:14, 6:46, 7:02 and 7:16 P.M., Eastern Standard Time. The pictures show vividly that the earth is round. The earth's shadow appears as part of a circle of greater radius than the radius of the moon and differs in shape from the apparently elliptical terminator of the crescent moon that we usually see. The lunar craters show no shadows. All the expected characteristics of the shadow theory of a lunar eclipse are to be found.

Two photographs of longer (15 and 30 seconds) duration of exposure, obtained to show the illumination of the portions of the moon within the earth's umbra, show, as an unexpected feature, the major planet Uranus, on the limits of visibility to the unaided eye, appearing close to the moon as seen from Washington. While the eclipse was in progress, Uranus was seen and recognized by one of the staff who was watching the eclipse with the 26-inch refracting telescope. Uranus is the planet which was discovered and recognized to be a planet by William Herschel, in 1781, after it had been mistaken for a fixed star about 20 times during the preceding hundred years; it is the first planet which was added to the known solar system after the invention of telescopes.

J. F. HELLWEG
U. S. NAVAL OBSERVATORY

ARCTIC POTATOES

It is northward just now that the course of empire is taking its way—but an "empire," like an army, must crawl on its belly.

Perhaps the most notable example of this northward progress is the industrialization of the frigid Kola Peninsula above the Arctic Circle by the Soviet Government, which seeks to take advantage of the rich mineral resources. Cities have sprung up, but cities need truck gardens and in that region the temperature sometimes sinks to around 25° F., the killing frost stage, in early August.

So the government has set up an Arctic plant breeding station there, and from this station have just come reports of the first success in breeding a potato highly resistant to freezing. At elevations as high as 5,000 feet in the Andes the Russian plant explorer, S. V. Juzepezuk, found a wild potato which did not seem to be injured by anything less than a killing frost during its blossoming season. With dark green leaves more than twice as thick as ordinary potato leaves growing in a rosette which almost hugs the ground, this vegetable withstood cold of 18° F. without apparent injury in North Russia.

It bears tubers, however, only under the twelve-hour day of the equatorial regions and only barren roots under the twenty-four hour day of North Russia's summer. It produced, however, an abundance of seed balls, according to the account just published in the *Comptes Rendus* of the Soviet Academy of Sciences by L. A. Dremliug, one of the staff of the polar station.

Six years ago, after many futile attempts, the first successful cross was made between this wild potato and a variety of the potato of agriculture, *Solanum tuberosum.* The cross was less frost-resistant than the wild plant of the high Andes, but still it withstood temperatures of 27° F. without injury.

The hybrid remained, however, a short-day potato. Transferred from the Soviet Potato Institute garden at Moscow to the Kola Peninsula it produced seed balls but not tubers. The next step was to make a cross between this hybrid and another variety of *Solanum tuberosum,* thus producing a triple hybrid with two thirds of its genes those of the domestic vegetable.

This was accomplished only with great difficulty. The experiment finally succeeded, according to Dr. Dremliug's account, only when the cross was made at the end of August when the temperature was steadily close to the freezing point. Only a very few seeds were obtained, only seven of these produced plants when planted the next year, and only two of these plants yielded any tubers. The tubers themselves were about the size of hickory nuts.

When these were used as seed potatoes the next year, however, the results were quite different. The plants which sprang from the cuttings resembled the Andean ancestor in their dark-green, thick leaves growing in a ground-hugging rosette. They flowered in profusion and bore seed balls. The tuber production under long-day conditions remained inconsequential, but when the plants were grown in cold frames in which the light could be regulated they produced good yields. They withstood temperatures of 25° F.

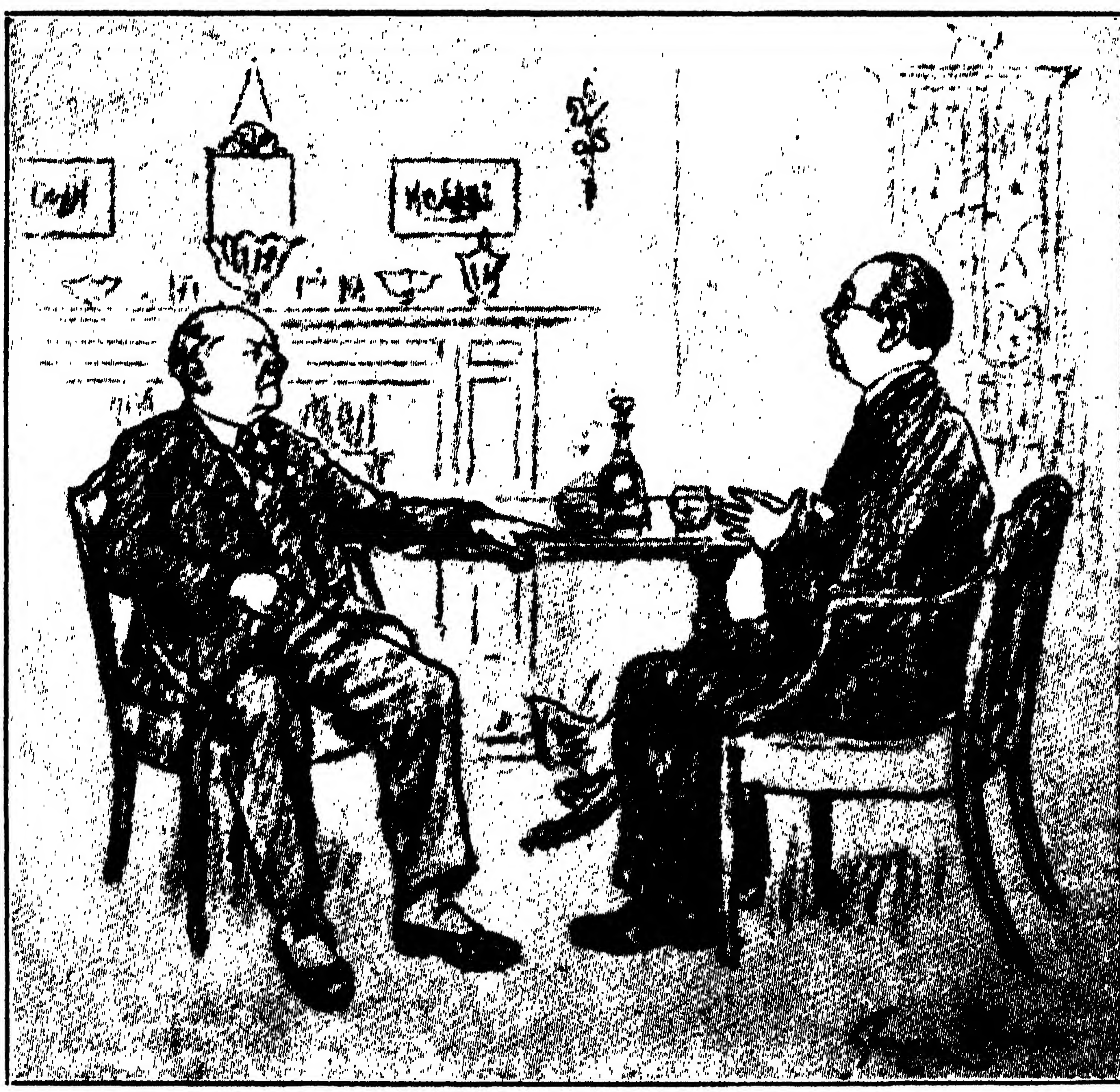
The problem of obtaining a good yield in the open field still remains to be solved, but it has not been advanced to the next stage—the back-crossing with other varieties of the domestic potato. The Soviet botanists have high hopes that one or another of the crosses will yield a long-day potato which will retain the frost-resistant character of the wild potato of the Andes.

They have apparently, Dremliug says, crossed the first great hurdle of producing fertile crosses. The flowers must be pollinated at close to freezing temperatures. The cold-resistant quality of the triple hybrid is apparently associated in some way, he says, with the fact that it has double the number of chromosomes in all its tissue cells as does the ordinary potato. About the same effects as are achieved with colchicine by American experimenters, he believes, are brought about by the hybridization in frigid temperatures.

Successful breeding of a frost-resistant potato might well be the turning point in the history of the Far North, both in the Old and New Worlds. The eyes of Canada as well as those of Russia are turned northward, and the great Arctic empire of Alaska remains largely virgin territory. Canadian pioneers and missionaries have grown potatoes successfully "north of sixty," it was reported at the American Association for the Advancement of Science meetings at Ottawa last summer. But as yet the crop is undependable and an early, severe frost will ruin it.

THOMAS HENRY

THE STUDENT OR THE FISH



—*From Punch*

PROFESSOR OF ZOOLOGY: "I DON'T TRY TO REMEMBER ANY STUDENTS' NAMES; EVERY TIME I REMEMBER THE NAME OF A STUDENT I FORGET THE NAME OF A FISH."

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